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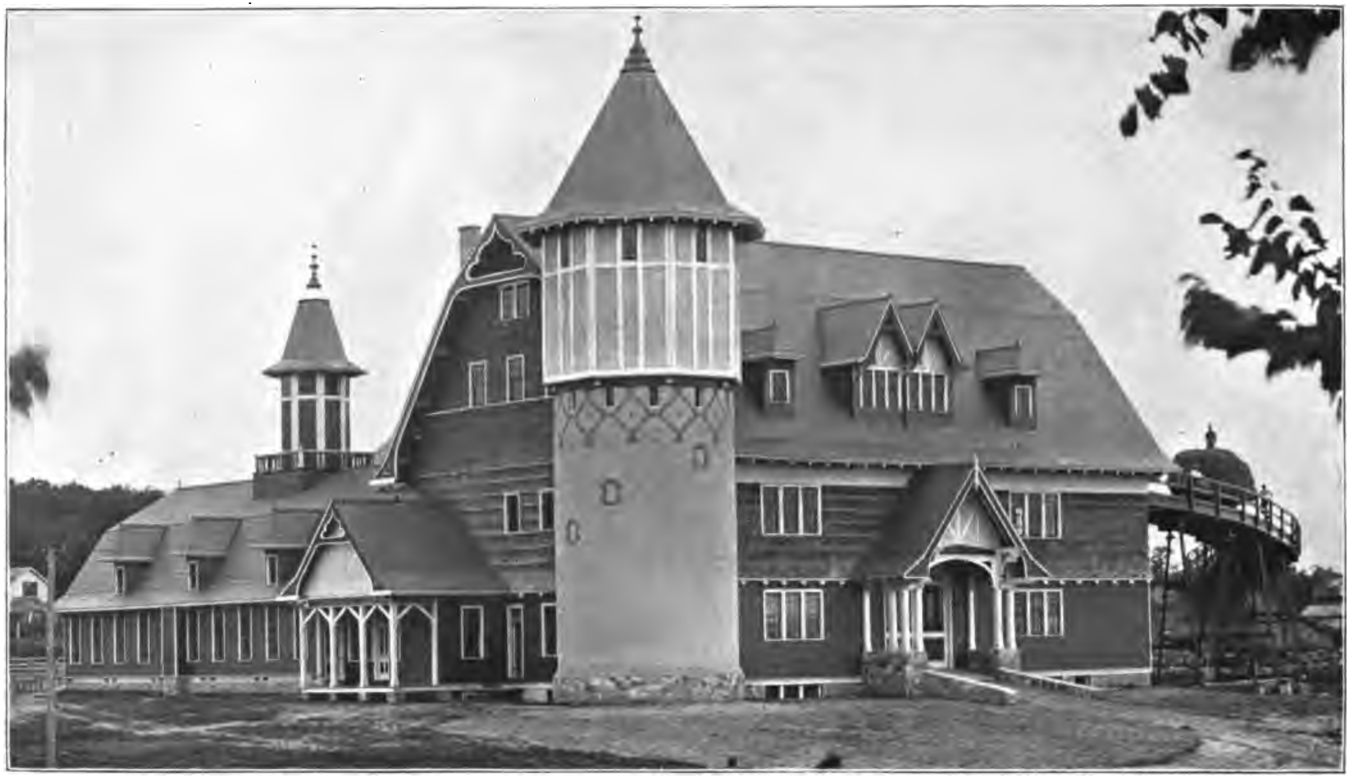

Dairy Barn and Stock-Judging Building, College of Agriculture, University of Wisconsin.

FIFTEENTH ANNUAL REPORT

OF THE

Agricultural Experiment Station

OF THE

UNIVERSITY OF WISCONSIN.

For the year ending June 30, 1898.

MADISON, WIS.:
Democrat Printing Company, State Printer
1898

☞The Bulletins and Annual Reports of this Station are sent free to all residents of the State upon request.

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General Offices and Departments of Agricultural Chemistry, Animal Husbandry, Bacteriology, Farmers' Institutes and Library, in Agricultural Hall, near University Hall, on Upper Campus.

Dairy Building and Joint Horticultural-Physics Building, west end of Observatory Hill, adjacent to Horticultural Grounds and Experiment Farm.

Telephone to Station Office, Dairy Building and Farm Office.

LETTER OF TRANSMITTAL.

MILWAUKEE, WIS, NOVEMBER 1ST, 1898.

To His Excellency, EDW. SCOFIELD,
Governor of Wisconsin:

I have the honor to transmit to you herewith, in accordance with law, the Fifteenth Annual Report of the Agricultural Experiment Station of the University of Wisconsin.

Respectfully,
JOHN JOHNSTON,
President of the Board of Regents.

REPORT OF THE DIRECTOR.

In presenting the Fifteenth Annual Report of the Wisconsin Agricultural Experiment Station to the farmers of Wisconsin, it is with pleasure that I am able to report continued advancement in the efforts to make the Station useful to the agricultural interests of the state. The large call for our publications, the very heavy correspondence and the steady flow of visitors to the buildings and grounds all combine to attest a growing appreciation of the work we are doing. The large attendance of students in the various agricultural courses shows likewise that our people recognize the importance of education and training in agriculture and are eager to use all available means to keep our state in the very front rank in all that pertains to agriculture.

The Station force.—Mr. H. A. Harding, assistant to Dr. Russell in investigations in dairy bacteriology, having been appointed to the chair of bacteriology in the New York Experiment Station, Geneva, left us in June for a period of study in Germany previous to entering upon the work of his new position. He is succeeded by Mr. H. V. Bassett, a graduate of this University.

Mr. W. L. Carlyle, for four years assistant in the Minnesota Farmers' Institutes, was elected by the Regents of the University in the fall of 1897 to succeed Prof. J. A. Craig of the department of animal husbandry, whose resignation was announced in the Fourteenth Annual Report. It is our desire to enlarge the facilities and the work of the department of animal husbandry in recognition of the first importance which live stock bears to the material interests of this commonwealth. The wants of our agricultural students also render such expansion imperative.

Investigations concerning milk.— The discovery of unorganized ferments in normal milk, as announced by Doctors Babcock and Russell in the Fourteenth Report of this Station, has excited keen interest among dairy scientists everywhere. Our appreciation of the wonderfully complex character of milk and its usefulness as a food for human beings of all ages and conditions, is certainly greatly increased by this discovery and through it we are led to a better understanding of this wonderful animal product. These investigators are continuing their studies in the same line and it is believed that much practical good in the end will come from their efforts. The cheese industry in Wisconsin, already of large magnitude, is capable of great development because the northern portion of this state is particularly adapted to that branch of dairying. The luxuriant growth of grasses, clovers and other forage plants, the cool, pure water everywhere so abundant, and the bracing, cool air of northern Wisconsin all combine to give us a territory unrivaled by any other state of the union for cheese production. The investigations in the making and curing of cheese at this Station have reached a point which calls for more ample and elaborate equipment for advanced studies, and it is earnestly urged that our next legislature make provisions for suitable appointments in this direction in connection with our present dairy building.

Sugar beet investigations.—During the spring of 1897 about 4,000 pounds of sugar beet seed were distributed among the farmers of the state. Through the generosity of the railroad companies nearly 2,000 packages of beets were transported to the station from the farmers in the fall without expense to them or to the Station, thereby saving many hundreds of dollars in freight bills. The onerous work of analyzing all these samples fell to Prof. Woll, who has summarized his efforts in Bulletin 64, copies of which were sent to all persons forwarding beets and to others whose names are on our mailing list. The results of the analyses show beyond question what has already been claimed, that Wisconsin is in the sugar beet belt of the United States.

For many years past the writer has maintained that it was possible and most desirable for this country to produce its own sugar and when that day arrived Wisconsin should at least produce the five million dollars worth of sugar consumed by her own people, if not a producer of sugar for other states as well. Through the acquisition of the Sandwich Islands and the results of the war with Spain it now appears probable that the sugar consumed in this country will once more be produced in tropical regions from the ribbon cane, and if this occurs there is no need of further effort on our part in studying the capabilities of our soil and climate in the way of producing sugar from the beet root. During the past season we have again sent out a considerable quantity of sugar beet seed, and Mr. Woll is continuing his studies of the beet on the Station farm. The situation is such, however, that it seems probable we shall drop this line of investigation because of the new conditions which have so suddenly and unexpectedly come upon us.

The new barn.—During the past year a barn for dairy cattle furnished with commodious quarters for judging live stock by our students has been completed on the University farm at a cost of about $16,000, with $2,000 additional for equipment. Our Agricultural College now has a dairy barn which is worthy in some measure of the great dairy industry pursued by our people, and in the room devoted to stock judging we have the comfortable quarters so much needed by the students of the Agricultural College.

The Dairy building.—Our Dairy building was erected at a time when there was no opportunity to study structures of its character designed for investigation and instruction; consequently it is not strange that after a period of eight years we find many changes necessary to give us a building which is modern in all its appointments and facilities.

It is hoped that our next legislature will make provisions for bringing this building up to the requirements of a large school and the needs of a corps of investigators busy at all times in studying dairy problems.

A central heating plant.—Gradually the buildings of the College of Agriculture, including the Experiment Station, are being grouped at the west end of Observatory Hill, their natural location. There is now needed a central heating plant to supply necessary heat for these buildings. There is a natural location for this structure between the Dairy and Horticultural buildings, and when constructed our buildings can be heated from it at a minimum expenditure of labor and fuel.

Visitors.—Each year thousands of farmers visit the Agricultural College and its Experiment Station. While not a day goes by without persons passing through the laboratories and inspecting live stock and crops at the farm, there is a tendency for this means of recreation and observation to assume an organized form in the shape of party-or excursion visits by which large numbers of individuals are present at one time. We plan to give this form of inspection and acquaintanceship direct assistance in the way of organization from the Station side during the coming year. It is hoped the railroad companies, recognizing the far-reaching effects of visits from the farmers in large bodies, will offer low rates to excursion parties desiring to inspect the Agricultural College and the Experiment Station. If such reductions can be secured it is believed that much benefit will accrue to all interested. Farmers are urged to take active steps to improve their opportunities in visiting their College and Station in order to be in closer touch with this work and to secure larger gains from its instruction.

Publications.—During the year ending June 30th, 1898, the Experiment Station issued the following publications:

Bulletin	No.	61,	15,000	copies,	21	pages each,	total	315,000	pages.
"	"	62	20,000	"	27	"	"	540,000	"
"	"	63	7,000	"	67	"	"	469,000	"
"	"	64	18,000	"	103	"	"	1,854,000	"
"	"	65	4,000	"	39	"	"	156,000	"
"	"	66	5,000	"	7	"	"	35,000	"
"	"	67	5,000	"	19	"	"	95,000	"
"	"	68	15,000	"	44	"	"	660,000	"
			89,000	"	327	"	"	4,124,000	"
Annual Report			15,000	"	338	"	"	5,070,000	"
			Total pages of report and bulletins					9,194,000	"

The above shows that during the year there were published by the Station eight bulletins and an annual report, containing in all more than 650 pages of printed matter, all prepared by the workers of the Station. During the year more than nine million pages of printed matter in the form of reports and bulletins were distributed from the Station nearly all going to the farmers of Wisconsin.

Available publications.—Most of our earlier publications are now out in print. We have on hand and will supply to residents of this state only, until exhausted, any of the following, upon request:

Eleventh Annual Report for the year 1894.
Twelfth Annual Report for the year 1895.
Thirteenth Annual Report for the year 1896.
Bulletin No. 16. **A New Method for Determining Fat in Milk (Short's test). July, 1888.**
Bulletin No. 19. **Notes on Ensilage. April, 1889.**
Bulletin No. 21. **Comparative Value of Warm and Cold Water for Milch Cows in Winter. October, 1889.**
Bulletin No. 22. **Reports on Oats, Barley and Potatoes for 1889. January, 1890.**
Bulletin No. 25. **Feeding Bone Meal and Hard Wood Ashes to Hogs Living on Corn. October, 1890.**
Bulletin No. 26. **Sugar Beet Culture in Wisconsin. January, 1891.**
Bulletin No. 27. **The Feeding Value of Whey. April, 1891.**
Bulletin No. 28. **The Construction of Silos. July, 1891.**
Bulletin No. 29. **Creaming Experiments. October, 1891.**

Bulletin No. 30.	Sugar Beet Experiments in Wisconsin for 1891. January, 1892.
Bulletin No. 32.	Feeding Grain to Lambs. July, 1892.
Bulletin No. 33.	Rations for Dairy Cows. October, 1892.
Bulletin No. 34.	Preventive Treatment for Apple Scab, Downy Mildew and Brown Rot of the Grape, Potato Blight and the Smut of Wheat and Oats. January, 1893.
Bulletin No. 35.	Insects and Diseases Injurious to Cranberries. April, 1893.
Bulletin No 37.	The Russian Thistle. October, 1893.
Bulletin No. 39.	Noxious Weeds. April, 1894.
Bulletin No. 40.	Tuberculosis and Tuberculin Test. July, 1894.
Bulletin No. 41.	Grain Feeding Lambs for Market. August, 1894.
Bulletin No. 42.	Destructive Effects of Winds on Sandy Soils and Light Sandy Loams, with Methods for Protection. October, 1894.
Bulletin No. 43.	The Agricultural, Horticultural and Live Stock Feature of a Portion of Wisconsin Tributary to Superior, January, 1895.
Bulletin No. 46.	Power Tests of Cream Separators. October, 1895.
Bulletin No. 48.	The Conn Culture (B 41) in Butter Making. January, 1896.
Bulletin No. 49.	The Maintenance of Soil Fertility: Commercial Fertilizers. March, 1896.
Bulletin No. 51.	The Marls of Wisconsin, June, 1896.
Bulletin No. 52.	A Comparison of the Babcock Test and the Gravimetric Method of Estimating Fat in Skim Milk. The Alkaline Tablet Test of Acidity in Milk or Cream. July, 1896.
Bulletin No 53.	Analyses of Licensed Commercial Fertilizers. July, 1896.
Bulletin No. 54.	The Restoration of the Consistency of Pasteurized Cream. August, 1896.
Bulletin No. 55.	Beet Sugar Production: Possibilities for a New Industry in Wisconsin. December, 1896.
Bulletin No. 60.	The Cheese Industry: Its Development and Possibilities in Wisconsin. May, 1897.
Bulletin No. 61.	The Constitution of Milk with Especial Reference to Cheese Production. September, 1897.
Bulletin No. 62.	Tainted or Defective Milks: Their Causes and Methods of Prevention. October, 1897.
Bulletin No. 63.	The Culture of Native Plums in the Northwest. October, 1897.
Bulletin No. 64.	Sugar Beet Investigations in Wisconsin During 1897. January, 1898.

Bulletin No. 65.	A Bacterial Rot of Cabbage and Allied Plants. February, 1898.
Bulletin No. 66.	Analyses of Licensed Commercial Fertilizers. April, 1898.
Bulletin No. 67.	Factory Tests for Milk. June, 1898.
Bulletin No. 68.	One Year's Work Done by a 16-Foot Geared Windmill. June, 1898.

Reports and bulletins wanted.—We have many calls from public libraries and from other experiment stations for copies of former reports and bulletins. The following are out of print and very much desired:

Annual reports of the Agricultural Experiment Station, I, III, IV, V, VI, VII.

Bulletins of the Agricultural Experiment Station (not Farmers' Institute Bulletins), 1 to 13, inclusive; also 15 to 17.

Friends of the Station who are not keeping files of our publications are earnestly urged to return to us any copies they can spare of the rare reports and bulletins. We will gladly pay a reasonable sum for any of the lacking numbers above noted. Readers should bear in mind that the documents asked for are Experiment Station bulletins and reports, and not bulletins of the Farmers' Institute, which is another branch of the Agricultural College.

The new mailing list.—The Station is now preparing a revised mailing list to embrace the names of those to whom its publication will be regularly sent. Each person on the old list (embracing over 13,000 names), has been notified of the fact by postal card and several thousand have renewed their applications. Farmers and others, residents of the state, wishing our publications should send in their applications, giving name, county and post office.

WHOLE CORN COMPARED WITH CORN MEAL FOR FATTENING SWINE.

W. A. HENRY.

Whether swine while fattening shall be fed whole corn or corn in the form of meal is a question of the highest importance to the western farmer. An examination of experiment station literature shows that only a very limited number of brief experiments have been made in this direction, and the subject must be considered an open one from this side. Realizing that more definite information should be at hand as a guide to the farmer, the writer began experiments in this line three years ago, the first results being reported in the Thirteenth Annual Report of this Station. Experiments were continued the following year and the results summarized in the Fourteenth Report. During the winter of 1897-98 a third series of trials were inaugurated with whole corn and corn meal for swine, with the results here reported.

DESCRIPTION OF FEEDING TRIALS WITH FATTENING SWINE RECEIVING SHELLED CORN AND CORN MEAL.

As in the previous trials, Iowa old corn, grading No. 2, yellow, was used. A carload of the corn was purchased in order to have representative grain of uniform quality throughout the trial. This grain probably contained from 12 to 13 per cent. moisture, judging from the analyses of corn from the same source and of the same grade used in the previous trials. Since old corn was used it is evident that the utility of grinding would be fully tested, for such grain must be more difficult of mastication than that of the crop fed the same season it is harvested. The corn fed as meal was reduced to fineness by grinding at a custom flouring mill in the vicinity, a new supply being secured from time to time in order that the meal might always be fresh and palatable. In all cases during the trials here reported one-third of the ration, by weight, consisted of wheat middlings, this proportion of the by-product of the wheat grain being deemed advantageous in order to secure the best returns for feed given. Even fattening pigs cannot be maintained with any profit on corn as the sole feed for a period of more than three or four weeks, and as this experiment was designed to run twelve weeks the addition of middlings to the ration was considered essential. The amount of feed consumed by the pigs in producing 100 pounds of gain is so small that it shows excellent returns. This indicates that not only was the ration satisfactory, but the pigs were thrifty and made good use of their feed.

THE PIGS USED IN THE TRIALS.

The experiment proper began December 8, 1897, after the pigs had been maintained for one full week on the same feed, this preliminary feeding period being customary with us in all trials of this character. Previous to the trial the pigs had been used in an experiment where they ranged on pasture consisting either of rape or red clover, with grain in addition as described elsewhere in this report. The pigs were all farrowed on the Station farm in April and early in May, 1897. They were grade Berkshire and Poland-Chinas, the sires being pure-bred animals. A bunch of 16 pigs was divided into two lots of eight each. The feed for Lot I was as follows: Twice each day the pigs were given a quantity of shelled corn in the feeding trough. When this was consumed wheat middlings were placed in the trough and water added to form a thick slop. As before stated, the middlings weighed half as much as the corn fed, thus constituting one-third of the ration. Lot II received a ration consisting of two parts corn meal and one part middlings, by weight, mixed with water in the trough to form a rather thick slop. Warm water was used. Salt and water were freely supplied to the pigs and in each pen there was placed a liberal supply of soft coal ashes. At the same hour of the day once each week the pigs were driven separately over the scales and their weights recorded. The second trial reported in the tables is in all particulars a duplicate of the first trial. Thus 32 pigs in all were used, 16 getting corn meal and 16 whole shelled corn.

TABLE I.—*Showing the results of feeding corn meal and middlings to fattening pigs — First trial.*

LOT I.	FEED EATEN.		WEIGHT AND GAIN OF PIGS.								
	Corn meal.	Middlings.	B* 1	B 2	B 3	S 4	B 5	B 6	B 7	B 8	Total weight and gain.
Weight at beginning Dec. 8, 1897	Lbs.	Lbs.	Lbs. 211	Lbs. 210	Lbs. 199	Lbs. 177	Lbs. 163	Lbs. 177	Lbs. 199	Lbs. 160	Lbs. 1,496
Weekly gain:											
1st week ...	270	135	9	10	11	10	12	13	10	11	86
2d week....	306	153	15	13	10	8	11	14	14	8	93
3d week....	282	141	11	22	14	15	11	7	17	6	103
4th week...	258	129	8	15	3	8	8	8	9	11	70
5th week...	252	126	12	11	15	9	11	19	8	5	90
6th week...	252	126	13	14	14	11	10	12	9	10	93
7th week...	252	126	9	10	8	12	10	9	9	6	73
8th week...	252	126	7	2	10	5	8	11	8	7	58
9th week...	252	126	13	17	9	10	11	11	8	8	87
10th week...	252	126	7	11	13	12	9	11	10	9	82
11th week...	252	126	11	13	12	8	6	15	14	6	85
12th week...	252	126	8	13	10	11	10	5	7	8	72
Feed eaten and final weights Mar. 2, 1898..	3,132	1,568	334	361	328	296	280	312	322	255	2,488
Total gain.	....	....	123	151	129	119	117	135	123	95	992

* B = Barrow. S = Sow.

TABLE II.—*Showing the results of feeding shelled corn and middlings to fattening pigs—First trial.*

LOT II.	FEED EATEN.		WEIGHT AND GAIN OF PIGS.								
	Shelled corn.	Middlings.	B* 1	B 2	B 3	B 4	B 5	B 6	S 7	B 8	Total weight and gain.
Weight at beginning, Dec. 8, 1897........	Lbs.	Lbs.	Lbs. 184	Lbs. 182	Lbs. 190	Lbs. 152	Lbs. 180	Lbs. 195	Lbs. 203	Lbs. 188	Lbs. 1,474
Weekly gain:											
1st week.....	256	128	8	6	10	6	8	9	9	9	75
2d week......	252	126	16	9	8	5	10	10	14	11	83
3d week.....	226	113	9	14	7	12	9	12	7	9	79
4th week....	227	113½	7	7	4	5	8	7	10	8	56
5th week....	238	119	13	11	10	4	6	9	13	12	78
6th week....	225	112½	12	7	7	13	8	7	7	6	67
7th week....	224	112	7	7	6	6	6	9	11	7	59
8th week....	224	112	7	12	6	3	6	11	14	10	69
9th week....	224	112	13	12	12	6	6	11	7	8	75
10th week...	214	107	8	11	7	6	8	10	8	9	67
11th week...	224	112	5	8	7	6	11	4	12	9	62
12th week...	224	112	6	9	7	0	9	13	5	11	60
Feed eaten and final weights Mar. 2, 1898...	2,758	1,379	295	295	281	224	275	307	320	297	2,304
Total gain.	....	....	111	113	91	72	95	112	99	109	830

* B = Barrow. S = Sow.

TABLE III.—*Showing results of feeding corn meal to fattening pigs — Second trial.*

LOT I.	FEED EATEN.		WEIGHT AND GAIN OF PIGS.								
	Corn meal.	Mid-dlings.	B* 1	B 2	B 3	S 4	B 5	B 6	B 7	B 8	Total weight and gain.
Weight at beginning, Dec 8, 1897	Lbs.	Lbs.	Lbs. 164	Lbs. 176	Lbs. 180	Lbs. 221	Lbs. 183	Lbs. 205	Lbs 174	Lbs. 171	Lbs. 1,474
Weekly gain :											
1st week....	270	135	7	11	11	19	12	15	10	10	95
2d week	306	153	14	7	6	10	10	12	7	14	80
3d week	282	141	9	11	16	20	11	18	14	10	109
4th week ...	240	120	6	7	8	17	9	15	13	11	86
5th week ...	252	126	8	10	8	8	11	8	7	10	70
6th week...	252	126	8	12	15	15	8	12	16	17	103
7th week...	252	126	7	15	9	15	10	15	9	7	87
8th week...	252	126	6	15	7	14	9	10	10	14	85
9th week...	252	126	6	11	11	14	13	10	10	7	82
10th week...	252	126	7	15	12	10	14	11	12	9	90
11th week...	244	122	6	10	0	7	14	14	18	20	89
12th week...	224	112	3	10	2	12	10	5	8	4	54
Feed eaten and final weights Mar. 2, 1898 .	3,078	1,539	251	310	285	382	314	350	308	304	2,504
Total gain..	....	....	87	134	105	161	131	145	134	133	1,030

* B = Barrow. S = Sow.

TABLE IV.—*Showing results of feeding shelled corn to fattening pigs.—Second trial.*

LOT II.	FEED EATEN.		WEIGHT AND GAIN OF PIGS.								
	Shelled corn.	Mid-dlings.	B* 1	B 2	B 3	B 4	B 5	B 6	S 7	B 8	Total weight and gain.
Weight at beginning, Dec. 8, 1897.......	Lbs.	Lbs.	Lbs. 223	Lbs. 185	Lbs. 171	Lbs. 163	Lbs. 182	Lbs. 191	Lbs. 175	Lbs. 181	Lbs. 1,471
Weekly gain:											
1st week....	256	128	7	6	8	6	3	12	4	9	55
2d week....	252	126	12	11	11	5	15	11	14	10	89
3d week....	226	113	15	11	10	15	10	9	3	13	86
4th week...	227	113½	5	9	10	10	10	8	0	8	60
5th week...	238	119	13	11	10	10	11	9	11	5	80
6th week...	225	112½	10	11	13	10	8	15	11	10	88
7th week...	224	112	10	7	8	12	9	10	6	6	68
8th week...	198	99	5	0	7	7	6	7	9	4	45
9th week...	176½	88¼	5	7	5	8	7	6	6	6	50
10th week...	194½	97¼	5	7	4	7	6	5	5	5	44
11th week...	196	98	4	10	5	10	9	9	13	11	71
12th week...	196	98	8	7	8	4	11	10	9	6	63
Feed eaten and final weights Mar. 2, 1898..	2,609	1,304½	322	282	270	267	287	302	266	274	2,270
Total gain	....	....	99	97	99	104	105	111	91	93	799

* B = Barrow. S = Sow.

WHAT THE TABLES SHOW.

Reviewing the tables we observe that on the whole remarkably good gains were made for the feed supplied, considering the length of the trial, which lasted eighty-four days. Generally the largest gains were made early in the trial, as is usually the case with fattening animals. In order to present the results in a form for easier study the important items are condensed in the next table, which summarizes also the results of the trials in the same line for the two previous years. These are as follows:

Summary of three seasons' trials with shelled corn and corn meal for fattening swine.

	Average weight at beginning.	Average gain.	AVERAGE DAILY GAIN.		FEED FOR 100 POUNDS OF GAIN.	
			Corn meal ration.	Shelled corn ration.	Corn-meal ration.	Shelled corn ration.
1896.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
First trial, 9 pigs in each lot:						
Lot I, fed corn meal	346	150	2.14	....	443	....
Lot II, fed shelled corn	354	137	....	1.96	....	481
Duplicate trial, 10 pigs in each lot:						
Lot I, fed corn meal	223	108	1.54	....	487	....
Lot II, fed shelled corn	225	79	....	1.13	....	591
1897.						
First trial, 9 pigs in each lot:						
Lot I, fed corn meal	210	150	1.79	....	442	....
Lot II, fed shelled corn	212	109	....	1.30	....	501
Duplicate trial, 7 pigs in each lot:						
Lot I, fed corn meal	198	82	1.30	....	462	....
Lot II, fed shelled corn	183	79	....	1.25	....	424
1898.						
First trial, 8 pigs in each lot:						
Lot I, fed corn meal	187	124	1.47	....	473	....
Lot II, fed shelled corn	184	101	....	1.23	....	500
Duplicate trial, 8 pigs in each lot:						
Lot I, fed corn meal	184	129	1.53	....	448	....
Lot II, fed shelled corn	184	100	....	1.19	....	489
Average of six trials with 102 pigs	....	....	**1.63**	**1.34**	**459**	**498**

CONCLUSION FROM THREE YEARS' TRIALS.

By the last table we learn that during three years at the Wisconsin Station 102 pigs in all have been employed in feeding trials where corn meal was fed in comparison with shelled corn. In all of these trials wheat middlings formed a portion of the ration in order that the pigs might be kept in good health and make the proper gains. Fifty-one of the pigs received shelled corn for the major portion of the ration, and an equal number received corn meal from the same corn as was given to the first lot, ground at a custom mill.

These trials show that the pigs fed whole shelled corn made an average daily gain of 1.34 pounds, while the lots which were fed corn meal made an average daily gain of 1.63 pounds. This is a difference of .29 pounds daily, or about two pounds per week greater increase through feeding corn meal.

Coming to the last item in the table we learn that 459 pounds of the corn-meal ration produced 100 pounds of gain, live weight, with these pigs, while 498 pounds of the ration containing shelled corn were required for the same gain. Thus by grinding corn to meal 39 pounds of grain were saved on 498 pounds. This shows that about 8 per cent. of the grain may be saved by grinding when feeding old corn in combination with middlings to fattening swine.

A study of the total quantity of feed required by the different lots of pigs in these trials as summarized in the tables shows that the pigs getting corn meal uniformly consumed a larger quantity of feed daily than those fed whole corn. Through the larger consumption of feed the pigs were enabled to make a more rapid daily gain than those getting whole grain.

There have now been conducted at this Station trials with 102 fattening pigs in all, divided into equal lots in each trial, receiving shelled corn and wheat middlings in the one case, and corn meal and middlings in the other, the proportions always being the same in parallel trials and the trials usually lasting twelve weeks, with animals ranging from 180 to 350 pounds each at the beginning of the feeding period. It is shown by these trials that corm meal effected a saving of 8 per cent. over whole corn and the pigs receiving the corn meal gained about two pounds per week more than the others.

Practical feeders who examine these figures will probably be surprised at the comparatively small saving in the amount of corn through grinding. The higher value placed on corn meal in comparison with whole corn by feeders generally is perhaps largely due to the more rapid gains made by pigs receiving meal instead of whole grain.

It is our intention to continue these experiments in order to accumulate data which will establish the principles underlying this important matter.

FARM GRAINS FOR LAMBS BEFORE AND AFTER WEANING.

W. L. CARLYLE.

In 1895 Prof. Craig began a series of experiments at this Station to determine the relative values of the different farm grains when fed to young lambs before and after weaning. The results have been published from time to time in the annual reports of this Station.[1] The experiments here reported were planned by Prof. Craig and partially completed by him before his resignation in the fall of 1897. In taking charge of the experimental work of the Live Stock Department in November last year the writer continued the investigation with the results here reported.

In the spring of 1897 sixteen grade Shropshire ewes with their lambs, twenty-four in number, were selected for this experiment. These ewes were good high grades; they had proved good mothers and were all about equally good milkers. The lambs in each case were sired by a good pure-bred Shropshire ram. They were dropped during the first half of March. Care was exercised in grouping the ewes and lambs in order to have the different lots as nearly equal as possible. The same number of twin lambs were placed in each lot, and as nearly as possible the weight of each lot was the same. All the ewes included in the experiment received the same treatment. They were turned out together every day with their lambs on a run of blue grass pasture and were brought into their yards every night, receiving no extra feed of any kind.

Two pens were provided for each lot — one for the lambs only where they received their grain separate from the ewes. This was separated from the larger pen by what is termed a "creep," which allows the lambs to pass back and forth between the pens at their will, the openings being however too small to admit the ewes to the feeding pens of the lambs.

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[1] Twelfth Report, p. 40; Fourteenth Report, p. 37.

The sheep used in this trial were divided into four lots, four ewes and six lambs in each lot. Before beginning the experiment proper all the lots were fed for two weeks on a mixed ration of cracked peas, bran, oats and cornmeal, equal parts by weight. This was done to cultivate the tastes of the lambs to the different grains, as there has always been some difficulty in getting the young lambs to consume cornmeal or bran alone for the first few days.

The following table shows the amount of feed eaten and the gains made in each lot during the preliminary period of two weeks when all the lambs were getting the same food:

Results of preliminary period of two weeks when lambs were fed a combination of grains.

	Lot 1.	Lot II.	Lot III.	Lot IV.
	Lbs.	Lbs.	Lbs.	Lbs.
Weight at beginning, May 13	248	245	245	248
Weight at close, May 27	306	299	315	307
Total gain in two weeks	58	54	70	59
Grain eaten: Peas, bran, oats and cornmeal, equal parts	8.4	10.5	9.8	9 9

During the experiment proper the lambs in each lot were treated the same in all particulars, except that the grain was given as follows:

Lot 1. Six lambs were fed cracked peas.
Lot 2. Six lambs were fed bran.
Lot 3. Six lambs were fed whole oats.
Lot 4. Six lambs were fed cornmeal.

The period before weaning during which these rations were fed was ten weeks, and the period after weaning the same length of time, the same kind of grain being fed to each lot before and after weaning. The lambs had all the grain they would eat clean in each lot until weaning time, after which they were limited to one-half pound for each lamb per day. The tables following show the gain made by each lamb and the food eaten by each lot during two-week periods, both before and after weaning.

A grain ration composed entirely of bran has never given the best results when fed to very young animals. It is evidently too bulky and not easy enough of digestion and assimilation. Especially is this true when it is fed to lambs before weaning time. In looking over the results of this experiment, it will be seen that both before and after weaning the lot fed bran consumed less and made smaller gains than any other lot. The amount of bran eaten for 100 lbs. gain before weaning in lot 2 was much less than was eaten by lot 1 on cracked peas, and about equal to lots 3 and 4 that received oats and corn. After weaning when the lambs no longer received any nourishment from their dams the result is somewhat different, as it required a much larger quantity of bran to produce 100 lbs. of gain than it did in the case of either peas or corn.

Results of feeding experiment with farm grains for lambs before and after weaning.

LOT I.	FOOD EATEN.	GAIN IN TWO-WEEK PERIODS. *Before Weaning.*						
	Peas.	E* 1	E 2	E 3	E* 4	E* 5	E* 6	Total weight and gain.
Weight at beginning May 27th, 1897.	Lbs.	Lbs. 54	Lbs. 60	Lbs. 57	Lbs. 50	Lbs. 40	Lbs 45	Lbs. 306
1st two weeks	20	3	10	12	11	4	8	48
2nd two weeks	24	2	5	5	6	7	8	33
3rd two weeks	20	7	4	9	5	5	9	39
4th two weeks	32	6	7	7	11	7	3	41
5th two weeks	36½	4	4	4	4	6	4	26
Feed and gain	132½	22	30	37	37	29	32	187
		After Weaning.						
1st two weeks	44	10	6	3	6	4	6	35
2nd two weeks	35	5	6	2	5	3	4	25
2rd two weeks	42	3	—1	1	0	1	2	6
4th two weeks	42	1	4	3	5	2	3	18
5th two weeks	42	8	7	8	2	6	6	37
Feed and gain	205	27	22	17	18	16	21	121
Total feed and gain	337½	49	52	54	55	45	53	308
Final weight	....	103	112	111	105	85	98	614

LOT II.	FOOD EATEN.	GAIN IN TWO-WEEK PERIODS. *Before Weaning.*						
	Bran.	E* 1	E* 2	E* 3	E 4	W* 5	W 6	Total weight and gain.
Weight at beginning, May 27, 1897.	Lbs.	Lbs. 64	Lbs. 49	Lbs. 57	Lbs. 49	Lbs. 40	Lbs. 40	Lbs. 299
1st two weeks	4½	9	7	10	11	6	8	51
2d two weeks	11½	10	4	5	0	6	4	29
3d two weeks	15½	7	3	8	8	6	5	37
4th two weeks	26½	8	6	6	4	5	5	34
5th two weeks	38	5	9	4	2	6	3	29
Feed and gain	96½	39	29	33	25	29	25	180
		After Weaning.						
1st two weeks	35	3	2	7	6	3	4	25
2d two weeks	37	5	3	5	4	3	2	22
3d two weeks	39½	-1	0	—1	—1	—1	2	—2
4th two weeks	42	3	2	4	0	2	2	13
5th two weeks	42	4	4	5	6	3	5	27
Feed and gain	195½	14	11	20	15	10	15	85
Total feed and gain	291½	53	40	53	40	39	40	265
Final weight	....	117	89	110	89	79	80	564

E = Ewe. W = Wether. * = Twin.

Results of feeding experiment with farm grains for lambs before and after weaning.

LOT III.	FOOD EATEN.	GAINS IN TWO-WEEK PERIODS. *Before Weaning.*						
	Oats.	E* 1	E* 2	E* 3	E 4	W* 5	W 6	Total weight and gain.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weight at beginning, May 27, 1897.	....	55	45	41	48	62	64	315
1st two weeks	9	9	8	8	8	9	9	51
2nd two weeks	12½	8	7	6	6	8	6	41
3rd two weeks	18	5	6	5	6	5	7	34
4th two weeks	29½	10	5	8	7	9	9	48
5th two weeks	40½	8	6	3	7	9	4	37
Feed and gain	109½	40	32	30	34	40	35	211
		After Weaning.						
1st two weeks	45½	3	3	6	1	4	6	23
2nd two weeks	39½	4	5	3	4	2	5	23
3rd two weeks	42	1	1	0	−1	2	−1	2
4th two weeks	42	4	3	5	1	2	3	18
5th two weeks	42	3	6	7	7	6	1	30
Feed and gain	211	15	18	21	12	16	14	96
Total feed and gain	321½	55	50	51	46	56	49	307
Final weight	....	110	95	92	94	118	113	622

LOT IV.	FOOD EATEN.	GAIN IN TWO-WEEK PERIODS. *Before Weaning.*						
	Corn-meal.	W* 1	W* 2	E 3	W* 4	E 5	W* 6	Total weight and gain.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weight at beginning, May 27, 1897.	....	54	48	68	46	51	47	314
1st two weeks	7	8	6	10	10	8	9	51
2nd two weeks	15	6	8	6	9	9	9	47
3rd two weeks	20½	7	7	8	7	7	10	46
4th two weeks	33½	8	5	6	6	9	4	38
5th two weeks	44	9	7	2	7	3	7	35
Feed and gain	120	38	33	32	39	36	39	217
		After Weaning.						
1st two weeks	48	3	1	6	6	1	6	23
2nd two weeks	34½	8	8	9	7	6	8	46
3rd two weeks	42	2	−1	−4	−1	−2	−3	−9
4th two weeks	42	1	5	8	3	3	6	26
5th two weeks	42	9	7	6	7	7	4	40
Feed and gain	208½	23	20	25	22	15	21	126
Total feed and gain	328½	61	53	57	61	51	60	343
Final weight	....	115	101	125	107	102	107	657

E = Ewe. W = Wether. * = Twin.

Summary of the results of this experiment.

Number of lot	I.	II.	III.	IV.
	Peas.	Bran.	Oats.	Corn-meal.
	Lbs.	Lbs.	Lbs.	Lbs.
Grain eaten in ten weeks before weaning	132½	96	109½	120
Gain in ten weeks before weaning	187	180	211	217
Average daily gain before weaning	2.67	2.57	3 01	3.10
Grain eaten for 100 lbs. gain before weaning	70.8	53.3	51.8	55.3
Grain eaten in ten weeks after weaning	205	195.5	211	208.5
Gain in ten weeks after weaning	121	85	96	126
Average daily gain after weaning	1.72	1.21	1.37	1.80
Grain eaten for 100 lbs. of gain after weaning	169.4	230	219.7	166.2
Average amount of grain eaten daily	2.40	2.08	2.29	2.34
Average daily gain	2.20	1.89	2.19	2.45
Total grain eaten in twenty weeks	337.5	291.5	321.5	328.5
Total gain in twenty weeks	308	265	307	343
Total grain eaten for 100 lbs. gain	109.5	110	104.7	95.7
Cost of grain for 100 lbs. gain, cents	81.9	71.5	65.4	51.2

It is evident that with oats at 20 cts., corn 30 cts., and peas 45 cts. per bushel, and bran at $13.00 per ton, as far as cost is concerned, corn gave the best results, with oats ranking next and bran in the third place, while peas were the most expensive feed. It would seem that cracked peas are a very expensive feed when fed to young lambs, as they evidently consume more of them than they can properly assimilate or give returns for.

By referring to the tables giving the gain of each lamb in two-week periods, it will be seen that in the third period after weaning very few of the lambs made much gain, while one-half of them during this period lost in weight, though they still ate the regular ration of grain.

The records of the Washburn Observatory located on the University grounds, at the time of the experiment show that the average daily maximum temperature for this period was 82.89° F., while for the preceding period it was

73.9° F,, and for the two subsequent periods 70.71° F. and 70.5° F., respectively. It will also be noticed that during this period, the lot fed on cornmeal lost nine pounds, while the lot fed peas gained six pounds, the other two lots on bran and oats remaining about stationary. It would seem from this experiment that a rise in the average maximum temperature for two weeks of 9° F. had a marked influence on the rate of gain, and that this was especially true of the lot fed cornmeal. The hot, close weather evidently did not affect the lot fed on peas so much.

It is our purpose to repeat the experiments along this line until sufficient data have been gathered to establish some facts about the comparative value of different farm grains for lamb feeding.

RAPE VERSUS CLOVER FOR GROWING PIGS.

W. L. CARLYLE.

The details of this experiment like the preceding one were planned by my predecessor Prof. Craig. Its object was to determine the value of rape in comparison with clover as a factor in growing young pigs. On page 80 of the Fourteenth Annual Report of this Station Prof. Craig gives the results of two experiments in which rape was compared with an all-grain ration for growing young pigs. The experiment here described included nine weeks feeding beginning Sept. 6th and ending Nov. 8, 1897, with two lots of pigs, twenty in each lot. Six of the pigs in each lot were pure-bred Poland-China, the remaining fourteen being grades of mixed breeding but all having been sired by a pure-bred Poland-China boar. Each lot consisted of eight sows and twelve barrows. The pigs were between five and six months old at the beginning of the experiment and were nearly uniform in size and weight. The feed eaten before the experiment began was the same with both lots and consisted of cornmeal and shorts, equal parts, mixed with twice the quantity of skim-milk.

The pigs in Lot 1 were folded in the rape with a movable hurdle fence. They were allowed a very small area at first to guard against trampling down and wasting the rape. The area was enlarged every few days, as the rape was eaten down in the enclosed portion. Twice each day they were fed a liberal quantity of cornmeal and shorts, in the proportion of 2 parts of cornmeal and 1 part of shorts, by weight. This was mixed with water before feeding to form a thick slop. They also received plenty of fresh water to drink. This lot was provided with a very small run of blue-grass sod beneath some trees for shade.

The pigs in Lot 2 were allowed the run of a ten-acre field of clover that had been cut once in the first week of July. A second cutting was taken off one-half the field on August 18th. Owing to the very dry weather prevailing at the time the pigs were turned into the field, the clover was much withered and dried up, therefore the pigs did not thrive so well upon it as they might have done had the condition of the clover at the beginning of the experiment been more luxuriant. There was an abundance of shade in this field also. The grain fed both lots was the same in character and quantity each day. The pigs were given the same care and management in all particulars in both lots aside from the difference in feed just described.

One sick pig was dropped from each lot in the third period so that no account will be taken of them during any part of the experiment. The following table gives the result of this experiment in detail, showing the gain of each pig in both lots during each two-week period:

Rape versus clover for young pigs.

LOT I.	FEED EATEN.		WEIGHT AND GAIN IN TWO-WEEK PERIODS, OF PIGS ON RAPE.																			
	Corn-meal.	Shorts.	S 1	B 2	S 3	S 4	B 5	B 6	B 7	S 8	B 9	B 10	B 11	B 12	B 13	B 14	S 15	S 16	S 17	S 18	B 19	Total weight and gain.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weight at beginning..	....	....	123	137	120	127	111	88	105	120	112	117	105	104	118	127	96	91	94	98	118	2,111
1st 2 weeks..	590	295	11	15	15	14	8	6	11	13	18	13	13	12	13	15	11	15	13	13	4	233
2d 2 weeks..	560	280	11	10	13	12	11	12	8	9	12	12	4	9	11	3	7	9	13	10	13	189
3d 2 weeks..	627½	313¾	12	18	14	19	12	9	16	18	19	13	11	12	8	13	11	10	15	12	6	248
4th 3 weeks..	630	315	11	13	20	12	10	10	9	18	9	10	16	10	8	11	5	11	13	12	17	225
5th 1 week...	315	157½	9	7	11	4	9	8	8	11	9	5	9	7	7	9	5	7	8	7	8	148
Total feed and gain.	2,722½	1,361¼	54	63	73	61	50	45	52	69	67	53	53	50	47	51	39	52	62	54	48	1,043
Final weight	....	....	177	200	193	188	161	133	157	189	179	170	150	154	165	178	135	143	156	152	166	3,154

S = Sow. B = Barrow.

Rape versus clover for young pigs.

LOT II.	FEED EATEN.		WEIGHT AND GAIN IN TWO-WEEK PERIODS, OF PIGS ON CLOVER.																			
	Corn-meal.	Shorts.	S 1	S 2	S 3	S 4	S 5	B 6	B 7	B 8	S 9	B 10	B 11	B 12	B 13	B 14	S 15	B 16	B 17	B 18	B 19	Total weight and gain.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs,	Lbs.	Lbs.	Lbs.	Lbs.
Weight at beginning.	....	....	122	131	132	125	100	119	103	103	112	105	98	113	113	104	98	98	98	113	104	2,091
1st 2 weeks..	590	295	6	14	16	13	10	4	7	5	17	11	5	16	9	11	10	10	12	6	10	192
2nd 2 weeks .	560	280	10	13	16	15	10	—1	0	10	15	18	6	0	6	8	11	19	9	11	11	187
3d 2 weeks...	627½	313¾	24	22	26	24	13	18	12	13	18	19	14	11	17	18	15	18	19	18	25	334
4th 2 weeks..	630	315	7	14	14	12	6	5	18	5	13	10	5	5	—2	0	8	9	0	5	7	141
5th 1 week ..	315	157½	5	5	5	6	5	2	5	2	3	4	2	3	4	5	5	3	3	6	4	77
Total feed and gain.	2,722½	1,361¼	52	68	77	70	44	28	42	35	66	62	32	35	34	42	49	59	43	46	57	941
Final weight	....	....	174	199	209	195	144	147	145	138	178	167	130	148	147	146	147	157	141	159	161	3,032

S = Sow. B = Barrow.

Summary of results of rape versus clover experiment.

Number of lot	I.	II.
	Rape.	Clover.
	Lbs.	Lbs.
Weight of pigs at beginning	2,111	2,091
Weight of pigs at close	3,154	3,032.1
Grain eaten, ⅓ shorts, ⅔ cornmeal	4,083.75	4,083.75
Total gain made	1,043	941
Average gain of each pig during experiment	54.89	49.52
Average daily gain per pig	.87	.78
Average daily gain in three last weeks	17.76	10.38

This experiment would seem to indicate that pigs, averaging about six months old, when pastured on rape will make a more rapid gain than a similar lot pastured on clover, the feed and management in other respects being the same. The result in this trial was a gain of five and one-third pounds for each pig in nine weeks in favor of the rape. Taking only the three last weeks of the experiment the gain of the nineteen pigs in favor of the rape over clover was seven and one-third pounds, while for the first six weeks the gain was in favor of the clover. This opens up a vast field of research to be developed in comparing these two crops. Did the rape crop have a more beneficial effect on the digestive and assimilative powers of the pig than the clover? Did the clover become less nutritious or less palatable during the latter part of the experiment, or did the rape increase in palatability and nutritive properties as the season advanced? These and other questions remain to be solved in future experiments, one of which is in progress this season.

The pigs on the rape were remarkably thrifty all through the experiment. They evidently relished the rape during the whole period and it apparently had a beneficial effect in regulating the bowels.

The nineteen pigs of Lot I during the nine weeks of the experiment ate the rape from 29,442 sq. feet of ground, or about two-thirds of an acre.

Farmers not having a suitable clover pasture for their brood sows and young pigs will do well to sow a small piece of rape at successive periods during the spring months. These may be pastured off in turn. When a plot is eaten off and the hogs removed, the rape immediately starts to grow again from the root and will usually be ready to feed off again in from six to eight weeks under favorable conditions of soil and season. In the manner given the pigs (and sheep as well) may be supplied a succulent feed throughout the growing season.

TESTS OF DAIRY COWS.

JOHN W. DECKER.

In recent years this Station has been called upon to make tests of dairy cows, and the results have been published in previous reports.[1] All such tests made the past year have been official tests for the Holstein-Friesian Association. They were made by S. I Murphy and E. E. Wyatt, and the results are herewith given.

Sworn detailed reports showing the weights of milk and per cent. of fat at each milking were made, and in each case a composite check sample was submitted to the writer for analysis, and the tests of these samples corresponded in each case with the results reported.

Lack of space prevents a detailed report of the weight of milk and fat test at each milking, but the general facts of the tests of ten cows are given in the following table:

Table giving results of official tests of Holstein Friesian cows.

The butter is here calculated as one-sixth more than the fat, in accordance with the rule adopted by the official chemists of U. S. experiment stations

Name of Cow.	Registry number.	Pounds of milk in seven days.	Av. per cent. of fat.	Pounds of fat in seven days.	Pounds of butter in seven days.	Age of cow.	Owner.	Post office.
Fracktze 2nd	40,125	332.7	2.44	8.129	9.481	2 yrs. 7 mo. 9 days.	H. E. Randall........	Hustisford.
Fannie Douglas 4th	41,943	323	2.73	8.834	10.306	2 yrs. 1 mo. 18 days.	H. E. Randall........	Hustisford.
Lottie Lass........	19,220	468.8	3.36	15.764	18.39	9 yrs. 3 mo.	H. E. Randall........	Hustisford.
Gewina 2nd's Lulu	41,945	370.7	3.51	11.96	13.95	2 yrs. 1 mo. 28 days.	H. E. Randall........	Hustisford.
Ollie Watson 3rd ..	41,944	301.9	2.41	7.266	8.471	2 yrs. 1 mo. 29 days.	H. E. Randall........	Hustisford.
Jessie Fobes 3rd...	32,286	562.3	3.04	17.11	19.96	6 yrs. 1 mo.	S. B. Jones & Sons.......	Hustisford.
Lady Longfield 3rd	39,945	400.55	3.22	12.892	15.04	3 yrs.	S. B. Jones & Sons.......	Hustisford.
Athalend Colantha	42,753	304.7	3.21	9.78	11.41	4 yrs. 2 mo.	Karlen & Co.	Monticello.
Elgin Belle 6th.....	......	282.9	3.68	10.417	12.15	1 yr. 11 mo.	Karlen & Co.	Monticello.
Daisy Rejaneta's Parthenea	......	227.3	3.13	7.11	8.25	1 yr. 9 mo.	Karlen & Co.	Monticello.

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[1] Reports of this Station 1894, XI, p. 205; 1896, XIII, p. 164; 1897, XIV, p. 35.

EFFECT OF VARYING STRENGTHS OF RENNET EXTRACT IN CURDLING MILK.*

JOHN W. DECKER.

During the past two years numerous experiments on the action of commercial rennet extracts have been made at this Station. Commercial rennet extracts are made by dissolving the soluble ferments (enzymes) from rennets in a brine solution. The extract then is probably a solution of the two enzymes, rennet and pepsin. Hansen's rennet extract was used in our experiments.

Apparatus used.— The apparatus used was what is known as Monrad's rennet test, consisting of a 160 c. c. tin cylinder for measuring the milk, a pint tin basin in which to coagulate the milk, a thermometer for observing temperatures, a 5 c. c. pipette for measuring the rennet, and a 50 c. c. graduated flask in which to make up a dilute solution of the commercial extract.

How a rennet test is made.—In making a test 5 c. c. of the strong extract is diluted with water to 50 c. c., and 5 c. c. of the dilute extract is used to coagulate 160 c. c. of milk at 86 degrees F. in the basin. The milk is set in a whirling motion and the point of coagulation is revealed when a few specks of charcoal scattered on the milk stop moving.

As stated above, 5 c. c. of the strong commercial extract is diluted to 50 c. c. in the graduated flask. In our experiments stronger solutions were made by using 5 c. c., 10 c, c., 15 c. c., 20 c. c., and 25 c. c., strong extract in 50 c. c.; this was multiplying the strength of the solution, 2 3, 4, and 5 times. These stronger solutions would be expected to coagulate the milk in ½, ⅓, ¼ and ⅕ the time required for the ordinary solution of 5 c. c. in 50 c. c., or stated in other words the time for congulation varies inversely as the strength of the solutions, but such was not the case, as is shown in the following table:

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*NOTE.—This and the following article, and the article on Handling sour milk for cheese, were prepared for the Fourteenth Annual Report but owing to lack of space were held over to this Report.

Table showing time required for 5 c. c. of rennet solutions of different strengths to coagulate 160 c. c. of milk at 86 degrees F.

Number of c. c. commercial rennet diluted to 50 c. c.	Times strength of rennet was multiplied.	Time required to coagulate 160 c.c. of milk at 86 degrees F.
5	1	90
10	2	51
15	3	41
20	4	32
25	5	28

If twice the amount of rennet in the 50 c. c. were twice as powerful in its action according to the above rule, it would require one-half the time to coagulate the 160 c. c. of milk or 45 sec. instead of 51 sec.; three times the amount would do the work in one-third of the time or 30 sec. instead of 41 sec., etc. The following table shows the calculated time for coagulation as compared with the actual time.

Table comparing actual time with calculated time required for coagulating 160 c. c. of milk with 5 c. c. of rennet extract of different strengths.

Number of c.c. of strong extract in 50 c.c.	Ratio of rennet to milk.	Times rennet strength was multiplied.	Actual time required for coagulation.	Calculated time required for coagulation.	Difference between actual and calculated time.
5..............	1:320	1	90 sec.	90 sec.	0 sec.
10..............	1:160	2	51 sec.	45 sec.	6 sec.
15..............	1:107	3	41 sec.	30 sec.	11 sec.
20..............	1:80	4	32 sec.	22 sec.	10 sec.
25..............	1:64	5	28 sec.	18 sec.	10 sec.

The same phenomenon is shown when curdling larger quantities of milk in the cheese vat in making cheese.

With the rennet test the point of coagulation is determined by the stopping of a speck of charcoal as has been described. In the cheese vat the point of coagulation is determined by inserting the finger and noting the manner in which the curd breaks. This does not give the point of coagulation as uniformly as in the rennet test, but the variation in the uniformity is probably not enough to change the point in question.

Table showing the lenghts of time required for different quantites of rennet to coagulate the milk.

Quantity of rennet used in 1,000 lbs. milk.	Ratio of rennet to milk.	Times rennet strength is multiplied.	Rennet test of the milk.	MINUTES IN CURDLING VAT OF MILK.	
				Actual time required.	Time calculated on a basis of 1 oz. or a ratio of rennet to milk of 1 : 1,000.
Experiment No. 1.					
1 oz...........	1:16,000	1	44 sec.	33	33
3 oz...........	1: 5,333	3	43 sec.	20	11
16 oz...........	1: 1,000	16	44 sec.	5	2
Experiment No. 2.					
1 oz...........	1:16,000	....	55 sec.	30	30—40
1 oz...........	1:16,000	....	50 sec.	40	....
4 oz...........	1:4,000	4	50 sec.	15	7½—10
4 oz...........	1:4,000	4	50 sec.	12	7½—10
16 oz...........	1:1,000	16	50 sec.	4	2—2½
16 oz...........	1:1,000	16	50 sec.	3	2—2½
Experiment No. 3.					
1 oz...........	1:16,000	....	30 sec.	33	33—30
1 oz...........	1:16,000	....	30 sec.	30	....
6 oz...........	1: 2,666	....	30 sec.	5	5—5½
10 oz...........	1: 1,600	....	30 sec.	4	3—3⅓
16 oz...........	1: 1,000	....	30 sec.	3	1⅞—2 $\frac{1}{16}$
16 oz...........	1: 1,000	....	30 sec.	3	1⅞—2 1
Experiment No. 4.					
1 oz...........	1:16,000	....	50 sec.	45	35—45
1 oz...........	1:16,000	....	50 sec.	33	....
4 oz...........	1:4,000	4	45 sec.	12	9—11¼
4 oz...........	1:4,000	4	45 sec.	14	9—11¼
16 oz...........	1:1,000	16	45 sec.	4	2⅕—2¾
16 oz...........	1:1,000	16	45 sec.	5	2⅕—2¾

The preceding tables give the time required for coagulation of the same milk at 86 degrees F. when different quantities of rennet were used:

These tables reveal some variations in time for curdling which were probably due to the difficulty in determining the density of the coagulum, but in one vat only was the calculated time as great as the actual time required. Though these results are not as strong evidence as might be wished for on account of the difficulty in determining the firmness of the coagulum, they confirm the results of the work done with the rennet test.

Viewing the results obtained practically, we must conclude that the usual method of comparing the money values of two brands of rennet extract, in which these values are considered as proportioned to the *times* required in an ordinary rennet test, is not correct. The relative *amounts* of the extracts required to coagulate the same quantity of the same milk, at 86 degrees F., should determine their relative money values.

THE ACTION OF RENNET IN WATERED MILK.

JOHN W. DECKER.

A number of experiments were conducted with the Monrad rennet test described in the previous article to determine the action of rennet in milk which had been more or less diluted with water, as this method of adulteration is occasionally found in cheese factories,

FIRST EXPERIMENT.

One hundred and sixty c. c. of milk at 86 degrees F. required 96 sec. for 5 c. c. of the dilute extract to coagulate it, while a mixture of 80 c. c. of the same milk with 80 c. c. of water required 345 seconds. It was difficult to determine the exact point of coagulation with such dilute milk, but three trials gave the same results.

This experiment shows that the addition of water to milk greatly lengthens the time required for coagulation.

SECOND EXPERIMENT.

The rennet test of the milk in the experiment was 21 seconds. Rennet tests made with milk watered in differentproportions gave results as follows:

Water.	Milk.	Per cent. of water in milk.	Rennet test, seconds.
1 part	1 part	50	35
1 part	2 parts	33⅓	26
1 part	3 parts	25	23
1 part	4 parts	20	22

This experiment agrees with the first in the fact that water in the milk increases the time required for coagulation and further shows that the increase in the length of time is greater, as the water is increased.

In experiment No. 1, the addition of an equal volume of water increased the time nearly four fold, while in the second experiment with the same proportion of water the increase in time was not quite two fold. There was a great difference in the acidity of the milks used in these two experiments as shown by the rennet tests of 96 sec. and 21 sec.

The rapidity of the rennet action is dependent on the amount of acid present in the milk, and the rennet test is used to measure the acid in the milk, but the increase of acid does not give a proportional decrease in the time required for coagulation, i. e., twice the amount of acid in the milk does not decrease the time required for coagulation by one-half. Therefore we would expect that if the dilution of a 96 second milk to 50 per cent. water increased the time of coagulation fourfold that a much less proportional length of time would be required for coagulation if a 21 second milk be diluted to 50 per cent. water as was shown by our experiments. The time of coagulation is shown by these experiments to be increased by the addition of water to milk, but the amount of such adulteration in a factory would probably not be enough to make a noticeable difference.

INVESTIGATION ON THE EFFECT OF SALT (NaCl) ON RENNET ACTION.

JOHN W. DECKER.

During the past year the following investigations have been carried on for the purpose of determining the influence of common salt on rennet action:

I. THE EFFECT OF BRINE USED IN DILUTING MILK.

A brine containing three pounds of salt to 20 pounds of water was made up. Milk of a rennet test of 30 seconds was diluted with different proportions of brine with the effect of increasing the time required in the rennet test as follows:

0 brine required	30 sec.
9 per cent. brine required	135 sec.
10 per cent. brine required	155 sec.
11 per cent. brine required	200 sec.
12.5 per cent. brine required	210 sec.
14 per cent. brine required	230 sec.
16.7 per cent. brine required	310 sec.

In our preceding experiment with water and sweeter milk (see p. 35) the time was increased but four fold with 50 per cent. water while in this case with 16.7 per cent. brine it was increased ten fold. The following table shows that while water alone retards the rennet action, the effect was greatly increased as the salt dissolved in the water was increased:

Dilution.	*Rennet Test.*
None	19 sec.
25 per cent. water	21 sec.
25 per cent. brine with 1 per cent. salt	34 sec.
25 per cent. brine with 5 per cent. salt	155 sec.

It is evident from these facts that salt retards the rennet action.

II. EFFECT OF DISSOLVING SALT IN THE MILK, ON RENNET ACTION.

This led us to dissolve salt in the milk directly, and it was found that five per cent. of salt stopped the coagulation entirely. Using smaller quantities of salt did not prevent coagulation but greatly hindered it. It is the practice with some cheese makers to add salt to over-ripe milk, and there are makers of brick cheese who add salt to the milk to check the development of gas.

AN EXPERIMENT.

We had eight vats of very ripe milk and salt was added to two of them.

The acidity was about .23 per cent., and the rennet test was 55 sec. After adding 1 per cent. of salt the time required with the rennet test was increased to 125 sec., but the acidity remained the same.

The next morning this milk was worked into cheese along with the other vats to which no salt was added. It required sixteen ounces of rennet to coagulate the salted milk and only three ounces to coagulate that in the other vats in the same time. This again shows the retarding effect of the salt.

The cheese was of excellent quality. It cured rather slowly and was not as soft and pasty as other cheese which had been made heretofore with ten and sixteen ounces of rennet extract.

On page 220 of the Eleventh Annual Report of this Station, we have shown the effect of salt to be the expulsion of moisture from the cheese, and slower curing. We are now suspicious that the slower curing was due, not only to less moisture, but also to this effect of the salt on the enzyme.

Ten and sixteen ounces of rennet is ordinarily an excess, for the cheese is made to cure too rapidly and it becomes pasty in texture and very strong in flavor. This we have seen was not the case when salt was added to the milk, the excessive rennet action having been checked.

If only the usual amount of rennet is used and salt is added to the milk, we will get the effect of adding too little rennet, namely, a slow curing and very likely a corky cheese. It is therefore our opinion that salt should not be added to milk that is to be made into cheddar cheese, and for brick cheese it will be preferable to add the salt to the curd and not to the milk.

III. EFFECT OF SALT BRINE USED INSTEAD OF WATER IN MAKING UP THE RENNET TEST SOLUTION.

We have seen that the effect of the salt in the brine used to dilute milk, and of salt dissolved in milk, was to check the rennet action. By making up our renne-ttest solution with brine instead of water the rennet action was also greatly hindered, for example:

A rennet test-solution made up with five per cent. of brine required 31 seconds to coagulate 160 c. c. of milk, whereas a solution made up with water required only 20 seconds. In another case the following results were obtained: When the rennet-test solution was made up with water the time required was 22 seconds; with 5 per cent. salt solution the time required was 28 seconds; and with 10 per cent. salt solution the time required was 41 seconds.

IV. EFFECT OF SALT IN COMMERCIAL RENNET EXTRACT.

The question that now arises is whether the salt used to preserve commercial extracts injures their effectiveness.

Four brands of rennet extract were obtained and a chemical analysis made of them with the following results:

Table showing analysis of different rennet extracts.

Brand of extract.	Rennet test.	Per cent. NaCl.	Organic matter.	Sp. g.	Boracic acid.
ilersons	92 sec.	16.69	4.13 per ct.	1.1495	Trace.
Hansens	95 sec.	17.21	3.73 per ct.	1.152	Trace.
E. C. & Gs. Diamond	98 sec.	16.66	4.59 per ct.	1.152	Trace.
Van Hasselts	101 sec.	16.04	5.32 per ct.	1.149	Trace.

Rennet tests made on the same milk with these extracts showed them to be nearly of the same strength. We were also surprised to find the percentages of salt so near together. The organic matter varied considerably, but that may have been due to and very likely was, matter other than the enzyme.

In order to find the probable effect of the salt in these extracts, an extract free from salt was made by soaking Bavarian rennets in distilled water. This filtered extract contained 2.23 per cent. of solids of which but .02 per cent. was ash. This as well as the commercial extract had a reaction.

Rennet tests with 5 c. c. of this salt free extract required 35 sec. for coagulation.

On adding 1 per cent. NaCl the rennet test was	38 sec.
On adding 5 per cent NaCl the rennet test was	40 sec.
On adding 10 per cent. NaCl the rennet test was.	42 sec.
On adding 15 per cent. NaCl the rennet test was	47 sec.
On adding 20 per cent. NaCl the rennet test was	52 sec.

This indicates that the salt used in commercial rennet extracts reduces the coagulating power of the enzyme.

Boracic acid dissolved in the milk checked the action of rennet upon it. Preservaline, which is boracic acid, should therefore not be allowed in milk received at a cheese factory. The same thing is true of formaline. Our previous experiments showed that when rennet extract is diluted it does not lose its power proportional to the dilution, and this was true of the salt free extract. (See p. 31.)

On a milk that required 62 sec. with the undiluted, dilutions of different proportions required as follows:

0 water required	62 sec.
33 per cent. water required 80 sec. instead of	90 sec.
50 per cent. water required 90 sec. instead of	124 sec.
75 per cent. water required 115 sec. instead of	248 sec.

This shows that the increased proportional power of rennet by dilution as shown in the previous article is independent of the salt in the extract.

CONCLUSIONS.

The conclusions that can be drawn from these experiments are as follows:

1. Salt in the milk retards the rennet action.
2. Salt in the rennet extract retards the rennet action.
3. The phenomenon of an increased proportional curdling power of dilute rennet extracts is independent of the salt that may be in the extract.

METHOD OF HANDLING SOUR MILK IN MAKING CHEESE.

JOHN W. DECKER.

Attention was called in the Eleventh Annual Report of this Station, to the fact that milk ready to be made into cheddar cheese will show about .22 per cent. of lactic acid by titration; that part of this acid reaction is due to the casein, or something that goes with the casein; that when the casein is precipitated by rennet the whey will titrate about .17 per cent. lactic acid, and when the acid develops in the whey to .21 per cent. or about the same as the milk titrated when set, the curd will stretch out ⅛ inch in fine strings on the hot iron, and the curd will be ready to dip. The length of strings are termed by cheese makers as so much acid on the hot iron.

Experience has taught makers that if much more than ⅛ inch of acid is allowed to develop in the whey a high acid cheese is likely to result.

We have sometimes been obliged to handle milk that titrated as high as .3 per cent. acid. Some makers wash such curds to get rid of the excess of acid, while others cook them up higher and faster than usual and then stir thoroughly on the racks to get rid of the whey.

A number of comparisons have been made between these two methods of handling such curds, and we have selected one day's work which illustrates the various points. There were eight vats, each containing 300 pounds of milk, and each was set with 4 ounces of Hansen's rennet extract.

Table showing details of the experiment.

	Curds firmed in water.				Curds firmed by stirring on racks.			
Vat. No.	A.	B.	C.	D.	E.	F.	G.	H.
Minutes in curdling	11	8	9	8	12	10	21	11
Minutes setting to dipping	40	23	23	22	45	40	46	46
Temperature cooked	108° F.	107° F.	108° F.	108° F.	110° F.	108° F.	108° F.	108° F.
Per cent. lactic acid in milk	.28	.31	.32	.29	.32	.32	.25	.30
Per cent. lactic acid in whey when curd was cut	.216	.230	.234	.234	.216	.202	.216	.194
Per cent. lactic acid in whey when drawn	.252	.252	.252	.252	.252	.230	.219	.227
Per cent. lactic acid in water used for firming	.130	.108	.108	.144	....	....	....	....
Per cent. fat in milk	.4	4.	4.	3.8	3.8	3.9	4.	4.
Per cent. fat in whey	.2	.3	.3	.3	.15	.3	2.	3.
Per cent. fat in water used for firming	.2	.2	.2	.2	....	....	....	....

The table shows that both acid and fat were washed out of the curds in the water used for firming them.

It is found that the acid is an important factor in firming the curd as it contracts it and expels the whey, and if such a curd be cut fine and kept thoroughly stirred it can be heated from 86° F. to 110° F. in fifteen or twenty minutes without injury; in fact, it is the only way of saving it.

If a curd can be firmed on the racks before it gets stringy, a pretty fair cheese can be obtained, but if the acid goes so far that the curd begins to stretch out into long strings the cheese is spoiled.

The whey should not be drawn while the curd is yet mushy, but it may be drawn while it is a little soft, and one will be surprised to see how fast it will firm up by stirring on the racks. We have been able to obtain cheese from such over-ripe milks both by the washing and the stirring processes that were clear in texture and did not show the least trace of high acid. This work has of course been done in small vats, and more difficulty in handling larger quantities of curd might be experienced.

QUALITY OF THE CHEESE.

Several batches of cheese made on the same days by the two methods of handling, were kept together for two months in the curing room. The cheese in which the acid was washed out by water developed ragged gas holes, and a flavor similar to cheese which is made up in summer without developing acid before pressing, and afterwards kept in a warm curing room. The cheese in which the whey was expelled by stirring was close in texture and of a very good flavor.

This would indicate that the acid has something to do in developing the flavor of a cheese, and since these experiments the advisability of washing curds has been doubted.

AN IMPROVED CURD TEST FOR THE DETECTION OF TAINTED MILKS.

S. M. BABCOCK, H. L. RUSSELL AND J. W. DECKER.

In determining the quality of milk for cheese-making purposes, it is necessary that consideration should be given not only to the nutritive worth of the various constituents (cheese yield, relation of fat to casein, etc.), but the actual condition of the constituents of the milk must be taken into consideration. The fat, casein and insoluble ash of the milk possess a real intrinsic value for cheese purposes, but if the milk contains micro-organisms that are capable of decomposing any of the above cheese-producing substances, or if the milk is impregnated with taints absorbed directly from the animal or after the milk is drawn, then its theoretical value as based upon the nutritive worth of its various elements is diminished to a greater or less degree by the operation of this second factor. The method usually employed to detect an "off" condition of the milk, up to the present time turns largely upon the acuteness of the sense of smell and taste of the receiver at the weigh can. To a very considerable extent this is a matter of education, but all such tests are sometimes unsatisfactory for the reason that they are merely opinions.

It is impossible in all cases to determine the quality of the milk as regards the presence of undesirable bacteria by tests that can be made at the weigh can. Much light, however, can be thrown upon this point by making what is known as fermentation tests. The general method by which these tests are made is to take a small quantity of milk and place it under conditions favorable for the development of bacterial life. By thus accelerating this development, it is possible to secure results in a few hours that would in the ordinary factory operations not develop until considerably later. By taking a sample of each patron's milk and subjecting the same to this test, it is possible to distinguish those milks which contain undesirable organisms from those that are suitable for cheese-making purposes. If the milk of a patron shows an undesirable condition day after day where it is subjected to a fermentation test, it indicates that some radical defect exists in his method of handling. Milks that show such deleterious fermentative changes should be excluded from the general supply, for the loss occasioned by the inferior value of the product is very frequently greater than the entire worth of the tainted milk itself. The state of Wisconsin alone loses hundreds of thousands of dollars every year from obnoxious fermentations that could be largely repressed, if greater care was used in receiving the milk.

FERMENTATION TESTS.

There are a number of fermentation tests of this character that vary only in some minor features. As usually employed these tests consist in placing a small sample of milk in a glass tube and then immersing the respective samples in warm water so as to facilitate fermentation. If it begins to ferment in the course of a few hours, gas-producing bacteria are abundant and their presence will be indicated by the accumulation of froth that is caused by the small bubbles of gas rising to the surface.

Such tests are frequently made in unsterilized vessels and are not protected from the air; under these conditions it is possible for bacteria to obtain entrance to the milk that may not have been in the original sample, and thereby false results are not infrequently obtained by these crude methods. Moreover, the activity of digesting bacteria is likewise hastened by this incubation of the milk so that milk may whey off before gas has had time to develop. Such milks are undesirable for cheese-making purposes; but too frequently a type of fermentation of this sort is neglected by the factory operator, he placing more reliance upon the evolution of gas than any other characteristic.

WISCONSIN CURD TEST.

In the course of our experimental work on the influence of gas-producing bacteria in cheese making, it became evident that some more accurate method for determining the presence of gas-forming bacteria was needed. To aid in these investigations the test to be described below was devised in 1895. This was first used for experimental work only, but practical application of the test in the field showed it to be so valuable a detector of tainted milks that it was introduced into our curriculum of studies in the Wisconsin Dairy School, and is generally known as the Wisconsin curd test. A constant use of this method by our students working under factory conditions has still further strengthened our estimate of its value as an agent which should be in the hands of every cheese maker in the state. We are firmly convinced that the use of this method will enable any factory operator to trace to its source a tainted condition in the milk arising from bacterial causes.

This test differs from the early fermentation tests in the following particulars. Instead of making the test in the fluid milk, a small pat of curd is produced by the addition of rennet and the whey which separates is poured off. In this way the milk serum which contains an abundance of fermentable sugar is removed, thus rendering a more accurate test possible. Again the development of gas and the amount of the same can be more easily traced in the curd than in the milk. Also, inasmuch as samples of curd conform more closely to cheese conditions, the method is an improvement over the use of the fluid milk.

A study of different milks by this test shows that almost all samples contain slight evidences of gas, if kept under conditions unfavorable for the keeping of milk, as is the case in the test.

During the heated season, the conditions are more favorable for the rapid development of these bacteria, and there fore, "gassy" fermentations are more troublesome in the summer months. A study of different herd milks for a considerable period of time shows, as might be expected, that this condition is not absolutely constant, but nevertheless, the presence of bad taints in certain milks has been found to be surprisingly uniform. In some herds the milk is so carelessly received and handled that gas forming bacteria are almost a constant accompaniment; in others, the undesirable condition is transitory, some days, gas appearing in quantities, to be followed by a period of comparative freedom from taints. In such cases the difficulty is temporary, the climatic conditions often being the deciding factor. In still other cases the herd milks are always free from any suspicion of taint. These represent in general the patrons that exercise the greatest care in their treatment of the milk. In case the curds are kept for 24 to 36 hours some gas will appear in even the very best milk, as gas producing organisms are present to some extent under the most favorable circumstances. In general, however, a tainted or defective condition, as revealed by the curd test, is usually traceable to the introduction of foreign matter such as filth, dirt or dust.

It not infrequently happens that a tainted condition may appear in the curd that is not associated with the production of gas. In some cases this arises from direct absorption of undesirable odors, either from the animal herself or from exposure after milking.

It frequently happens that digesting bacteria that dissolve the casein without the production of gas may also be present. In such cases, the casein passes partially into solution, and is lost in the whey. The taints caused by this class of organisms are peculiarly offensive. Milks that contain such bacteria in any considerable numbers give a materially diminished yield of cheese, and illustrate the unfairness of the guarantee principle that demands that a maker should make a pound of cheese from a certain quantity of milk regardless of conditions.

IMPROVISED CURD TEST.

A home-made test can be improvised that will give good results, but we would advise the use of one of the perfected tests as it is more convenient.

The apparatus for the improvised test consists of a wash tub (see Fig. 2) that is half filled with warm water, a set of pint fruit jars (C) for the different samples, a pipette (p) for measuring the rennet, and a case knife (k) for breaking the curd.

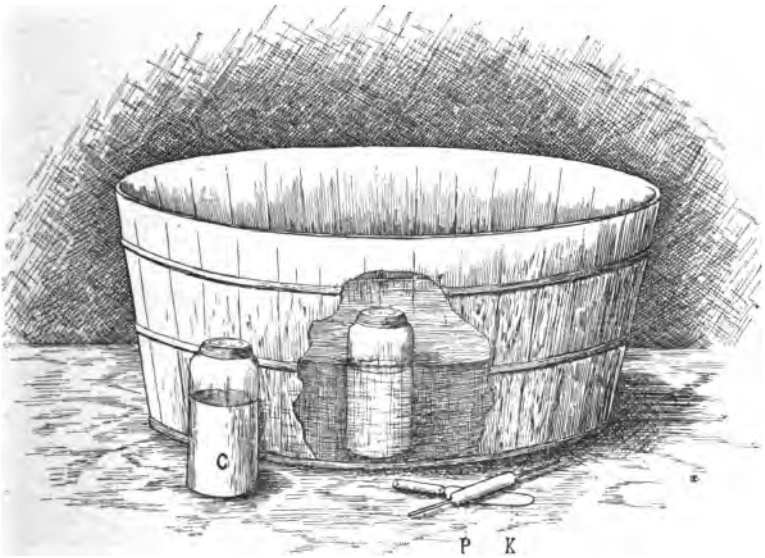

FIG. 2.—Improvised curd test. C, cans used to hold samples; P, pipette for measuring rennet; K, knife for breaking curd.

HOW TO MAKE A TEST.

To make a test, fill a jar half full of milk. Set samples in the tub and fill the same half full of warm water. Usually water at 115° F. will raise the temperature of the milk to the desired point, viz., 98°. If the milk is very cold to prevent cracking the jars care should be taken not to use too hot water.

When the temperature of the milk reaches 98° F., add to each sample by means of a pipette, ten drops of rennet extract and mix thoroughly. Allow the jars to remain undisturbed until milk is curdled, then break the curd into small particles by stirring with a case knife, in order to better expel the whey. In using thermometers for taking temperatures, or knife for cutting the curds, care should be taken to rinse after using in each sample so as to prevent the transference of many organisms from one sample to another.

The whey should be poured off as soon as the curd settles to the bottom, this process being repeated at frequent intervals until the curd mats into a solid mass. This expels the excess of whey which contains the fermentable sugar, thereby simulating cheese conditions more closely. The temperature of the surrounding water should be maintained from six to eight hours to favor a rapid development of the contained organisms.

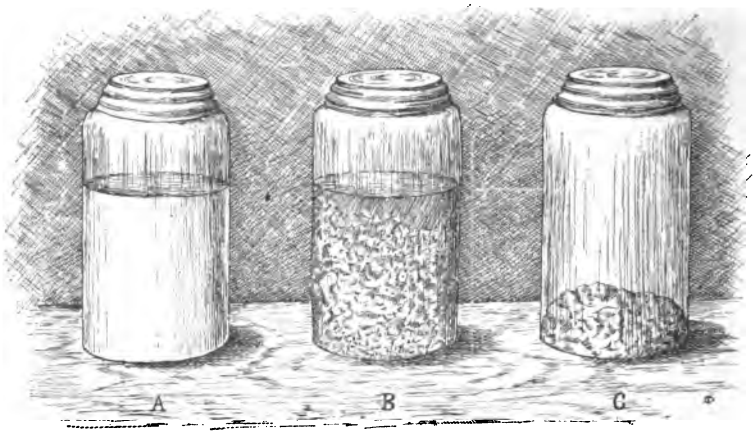

FIG. 3.—Showing different stages of test. A, milk; B, broken curd in whey; C, matted curd.

This improvised apparatus will enable any cheese maker to use the test with satisfactory results, but time can be saved and greater convenience secured if apparatus is devised for the particular purpose in hand. When the curd test is in constant use some such apparatus as that described below will be well worth the expense.

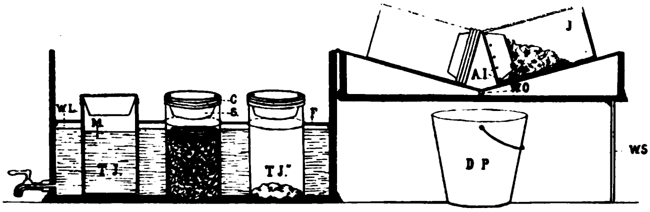

FIG. 4.—Section of Improved curd test. T J. T J"., Test jars showing different stages of test; W. L., water line; M, milk; F, frame; W. S., wire standard to support cover; A. I., drain holes; W. O., whey outlet; D. P., drain pail.

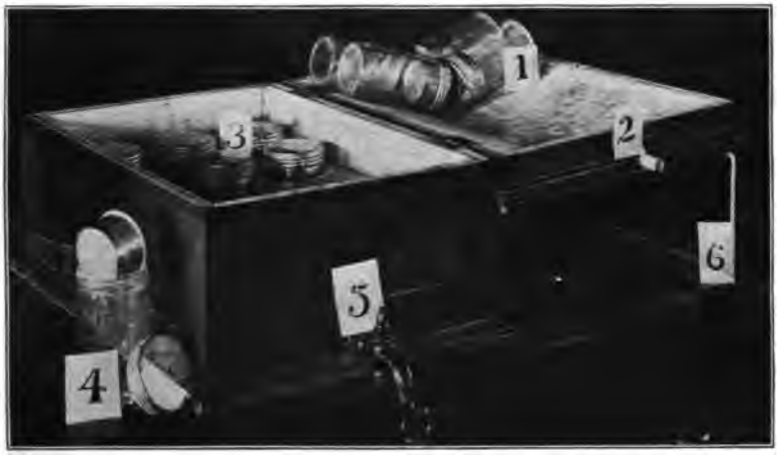

FIG. 5.—Improved curd test. 1, test bottles draining; 2, whey outlet; 3, test bottles in water tank; 4, test bottles in parts; 5, stop cock for water; 6, standard to support cover.

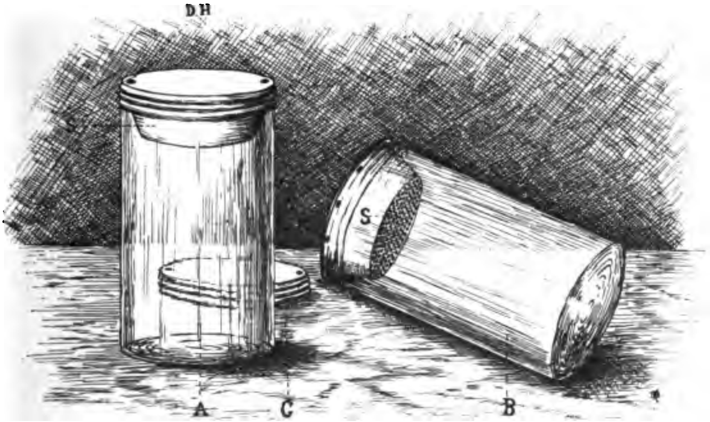

FIG. 6.—Improved test bottle. A, test bottle complete; S, sieve; D H, drain holes in cover; B, test bottle showing construction of cover. C, outer cover; S, sieve.

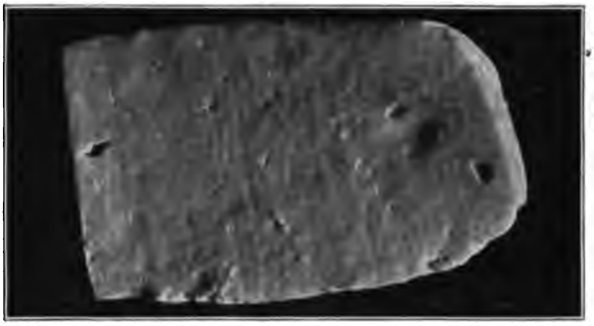

FIG. 7.—Curd from a good milk. Large irregular holes mechanical.

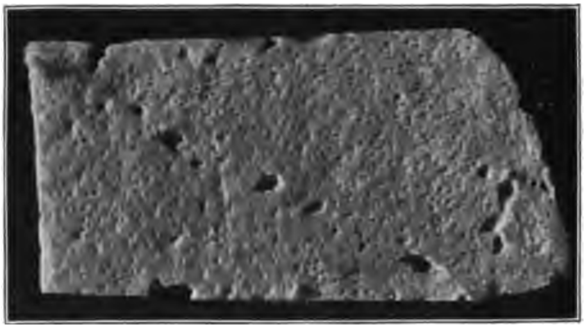

FIG. 8.—Curd from a bad milk. Large irregular holes mechanical, small pin holes due to gas.

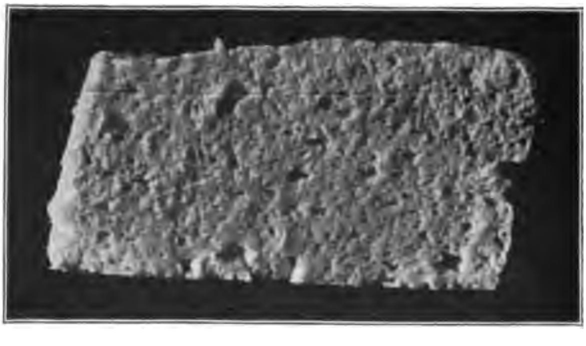

FIG. 9.—Floating curd from a very bad milk. Condition reached by further development of fig. 8, or a greater number of gas-producing bacteria.

IMPROVED CURD TEST.

The improved apparatus shown in figs. 4 and 5, has the following points of advantage over the improvised test already described:

1. A water box with a close fitting cover permits of a retention of the desired temperature for a much longer period of time than an open tub. This is important if the weather is cool.

2. A faucet in the bottom allows the water to be drawn off and replaced with warm water without handling the bottles, thereby saving time and labor.

3. A rack (P) holds the bottles (T. J.) in place; without this rack the bottles tip over easily in the water when the whey has been emptied.

4. The bottles have a large top and straight sides so that the curd can be more easily removed. The bottles are more easily cleaned on this account.

5. The strainer (S) in the top enables the operator to place the bottle in an inclined position to let the whey drain out. The whey can be thus more quickly and completely removed.

Apparatus of this kind has been constructed for our own use and we find it very satisfactory. Such apparatus can now be obtained of some of the dairy supply houses. As we have already received a number of inquiries concerning such apparatus, we would say that up to the present time A. J. Decker, Fond du Lac, and F. B. Fargo & Co., Lake Mills, have submitted apparatus to us which has met our approval.

INTERPRETATION OF RESULTS.

If the milk contains no deleterious bacteria the curd when cut will present a firm, even texture as shown in Fig. 7. If gas-producing bacteria are present the texture of the curd will be more spongy, the cut surface showing a number of holes varying in size, depending upon the prevalence and gas-producing ability of the undesirable bacteria as shown in figs. 8 and 9.

Care should be taken to discriminate between purely mechanical holes that are formed by the failure of the curd to mat closely and those caused by the formation of gas. Mechanical holes are irregular in form and more variable in size, while holes formed by gas are circular in outline and more uniformly distributed throughout the whole mass of curd. As gas continues to be formed the curd puffs up and some of the gas may escape into these mechanical openings, distending them, and giving them the appearance of regularly formed gas holes. The size of the gas holes in the curd is largely dependent upon the duration and activity of the fermentations. The longer the curd is allowed to ferment at a proper temperature, the larger and more numerous will be the holes. Even in a good milk, a few holes will develop if the curd is held for 24 hours or more, but the presence of a few "pin holes" within six hours need not condemn a milk unless accompanied by undesirable odors.

The conditions under which the curd test is conducted accelerate the fermentative action, so that a milk that might show no symptoms of gas formation until the cheese was on the shelf, would be detected when subjected to the curd test. Milks that are sufficiently contaminated to produce floating curds will show a very spongy texture in the test in a few hours. No hard and fast rules can be given for the interpretation of the results of the curd test, but an ordinary operator will very quickly learn to discriminate between milks that should and should not be accepted.

It should be borne in mind that the formation of gas is generally accompanied with the production of other decomposition products that possess more or less pronounced undesirable flavors and odors, and that the real injury to the cheese is due to this more than to the mere mechanical presence of gas.

It is also possible that taints may be produced by bacterial decomposition in cases where no gas is formed. This is particularly true with that class of organisms that act upon the albumen and casein instead of the milk sugar.

Those bacteria that find their way into the milk through the introduction of filth and dust are particularly prone to produce this change, and this type of fermentation is very often found during the summer months. In the curd test such milks are not condemned upon the texture of the curd but upon the odor which is more or less pronounced when the bottles are opened.

CONCLUSION.

In the hands of the factory operator this test is a valuable adjunct in enabling him to determine the presence of taints which might otherwise escape detection. The losses that accrue from these sources are in the aggregate very large and the difficulty hitherto has been that the cause of these troubles could not be located with sufficient accuracy to enable restrictive measures to be employed. The Wisconsin curd test fills this want and has been shown to be an efficient detective of tainted milks. It is therefore earnestly recommended that this test be employed in factories when difficulties of this sort are met with.

PASTEURIZATION EXPERIMENTS IN BUTTER MAKING.*

E. H. FARRINGTON AND H. L. RUSSELL.

Considerable interest in the methods of making pasteurized butter has been awakened among creamery butter makers during the past year. This has been largely due to the demand for export butter. The English market at certain seasons of the year offers higher prices than the American market, and this has directed the attention of American creameries to the kind of butter which the foreign market demands. Since the discovery by Storch in 1890, that the flavor of butter could be controlled by the use of a selected bacterial culture as a starter in pasteurized cream, this method of butter making has been rapidly developing, especially in Denmark, where 95 per cent. of the present output is made in this way.

Recognizing the necessity of carefully conducted experiments on the subject of pasteurization as applied to butter making, under American conditions a large number of experiments in regard to this question have been made at the University Creamery during the current season.

In Denmark two different systems are used, i. e., pasteurizing the whole milk before skimming, and pasteurizing the cream after separation. One of the advantages claimed for this first system is that the skim milk is pasteurized, a process that is necessary in such countries as Denmark, where bovine tuberculosis is present to such an alarming extent.

Our experiments so far have been entirely confined to a study of the first method where the milk was pasteurized before separation. The work here reported has been carried on from February to August, thus covering winter and summer conditions.

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* The full details of this work are to be found in Bull. No. 69 of this Station, which will be supplied to any one desiring the same.

Several points were had in mind in carrying out this work:

First, to see whether pasteurized butter would meet the demands of the American market.

Second, to test the efficiency of the pasteurizing machine used.

ARRANGEMENT OF APPARATUS.

The arrangement of the milk heaters and separators during the experiments is shown in Fig. (1). As the milk is received from the farmers, it is poured into one large vat from which it runs through a pipe that divides it into two parts, one of which is conducted to the heater and separator (see 1 in figure), and the other through the pasteurizer (2 in fig.) and separator (4 in fig.).

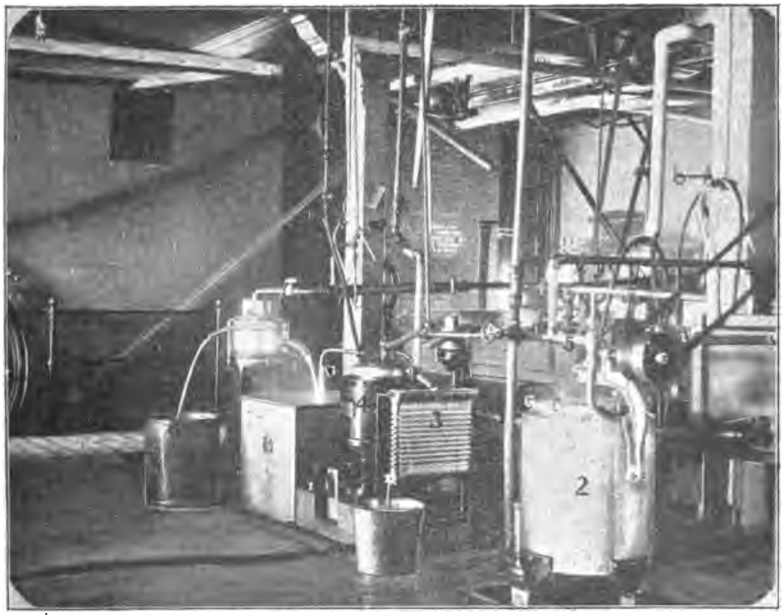

FIG. 10.—Arrangement of pasteurizing machinery during operation. 1, Milk heater; 2. Milk pasteurizer; 3. Cream cooler; 4. Separator.

The unpasteurized butter was made from milk heated to 85° F. or less, while that pasteurized was heated to 155° F. The cream was cooled either in the cream-ripening vat immediately after separation, or in a special cooler as it came from the separator. The cream ripening and churning operation were practically the same for both kinds of milk.

The butter was generally scored during the first week after it was made, but in some instances it was held in the refrigerator at the creamery or in the Chicago butter cellar, so that the first scoring of the butter was not made until two weeks after the butter left the churn. The scoring was done in every instance by Mr. D. C. Woolverton, butter expert of the Elgin Creamery Co. of Chicago, who reported the scores by package number. We are much indebted to this gentleman for the courtesy shown in thus aiding us in our experiments.

I. Efficiency of Reid's Pasteurizer as a pasteurizing machine.

In carrying on this series of investigations we have used the pasteurizer devised and loaned to us for this work by A. H. Reid, of Philadelphia, Pa.

The milk heater (2) is shown in Fig. (10). It is a double-walled tin cylinder into which the milk flows at the bottom and is heated during its passage to the outflow at the top. Heat is supplied by steam circulating between the walls of the cylinder and the milk is forced over this heated surface by a fan which revolves inside the cylinder at a speed of 300 revolutions per minute.

EFFICIENCY AS MEASURED BY BACTERIOLOGICAL EXAMINATIONS.

To determine the germ-killing efficiency of the machine, the milk was subjected to quantitative biological analyses. These were determined in the way usually employed in bacteriological laboratories, i. e., mixing a given quantity of milk with some nutrient culture medium and making "plates" of the same. For this purpose neutral nutrient gelatin was used.

Samples of milk were taken at the inflow and also at the outlet, and from the same, duplicate quantitative bacteriological determinations were made as follows:

TABLE 1.—*Effect of pasteurizing on germ content of milk.*

DATE.		NO. OF BACTERIA PER CC.	
		Unpasteurized sample.	Pasteurized sample.
March 14	Separator cream	64,517,000	852,800
March 23	Skim milk	74,560,000	1,225,000
	Whole milk	9,095,000	661,000
		9,780,000	600,000
March 28	Whole milk	80,000,000	228,000
			160,000
March 30	Skim milk	5,400,000	2,356,000
		5,770,000	2,482,500
April 4	Skim milk	5,190,000	87,400
			115,400
April 11	Skim milk	43,992,000	746,700
			934,000
April 28	Skim milk	11,603,000	218,400
		14,235,000	274,000
May 7	Skim milk	2,433,000	187,000
May 9	Skim milk	82,500,000	17,500,000

Any one familiar with quantitative bacteriological data knows that not much dependence can be put on figures of this class unless a large amount of such data is collected. Nevertheless from the number of observations recorded above, it is evident that the pasteurizing process as applied in the Reid machine exerted a strong germ-killing effect on the bacteria in the milk. It is impossible for us to institute comparisons with other kinds of continuous pasteurizing machines for so far as we know, no adequate data of this sort has been recorded.

We are able, however, to report comparative results with pasteurizing machines that are operated intermittently, such as are recommended for the preparation of milk for direct consumption. For the past four years we have had in operation a machine designed for this purpose by one of us (R) and the efficiency of this as to the destruction of bacteria contained in the milk has been the subject of special investigation. As a result of 108 analyses made on cream and milk before and after it was pasteurized, it was determined that 99.72 per cent. of the bacteria in cream and 99.83 per cent, in milk were destroyed. The average number of organisms in whole milk was reduced 3,674,000 to 6,140.*

That this was no unusual reduction but represents the every day working of the apparatus is proven in several cases by taking samples of milk pasteurized in the Russell vat and comparing them with those treated in the Reid machine.

		Bacteria per cc.
March 17	Normal whole milk	34,605,000
	Pasteurized in Reid machine	2,782,000
	Pasteurized in Russell vat	5,400
March 23	Normal whole milk	9,781,000
	Pasteurized in Reid machine	661,000
	Pasteurized in Russell vat	6,000

While it cannot be hoped that any machine having a continuous delivery can handle the milk as effectively as one operating in an intermittent manner, still we must measure the effectiveness of the process by these comparisons. These results are given somewhat in detail for the reason that the misleading claim has been advanced that this continuous type of machine is capable of absolutely sterilizing the milk, i. e., destroying all bacteria as revealed by bacteriological analysis. For instance, in one series reported it is said that "the whole milk contained 63,842 bacteria per cc. and a bacteriological analysis of same after pasteurizing showed no development in gelatin plates in 24 hours from whole milk and only two colonies from skim milk; at the end of 48 hours whole milk showed 5 colonies, cream 8 and skim milk 12."

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* 12th Ann. Rept. Wis. Agrl. Expt. Station, p. 159.

These results are entirely misleading, for it is evident to the bacteriologist that they were not carefully performed. In all probability the reaction of the media used for culture purposes was unsuitable for bacterial growth.

From a bacteriological point of view this type of machine destroys a large proportion of the organisms in the milk, but this is of necessity a fluctuating quantity and one that cannot well be controlled. Considerable emphasis has been laid upon this phase of the subject for the reason that there is a very general misconception concerning the efficiency of the pasteurizing treatment. A temporary application of heat can never effectually destroy all of these organisms that are in a vegetating stage, an ideal condition that is to be desired if the best results are to be gained from a pure culture starter.

EFFICIENCY AS MEASURED BY KEEPING QUALITY OF SKIM MILK.

At various intervals during the season about 30 lbs. of pasteurized and of unpasteurized skim milk were taken from the separators and left in the creamery room at the same temperature. The temperature and acidity of each one was observed at intervals, until both were sour. The pasteurized skim milk had a temperature of 130-150° F. when taken from the separator, but the 30 lbs. was such a small amount that it soon cooled to the temperature of the room. This helped to preserve the milk, as cooling after heating is an important factor in preventing the souring of milk. The unpasteurized skim milk had a temperature of 70° to 80° F. when it was taken from the separator. Eight such trials were made. Both lots of skim milk were taken from the separator at the same time so that they represented skim milk from the same lot of whole milk. It was found in every trial that the unpasteurized skim milk soured from twelve to twenty-four hours before the pasteurized, and in some cases the pasteurized skim milk was sweet after standing forty-eight hours. •

EFFICIENCY OF MACHINE FROM OPERATOR'S STANDPOINT.

In order to reduce to a minimum the time and labor of operating this machine, it was found necessary to have the milk and steam supplied to it almost automatically, as any fluctuation in the amount of milk or steam entering the heater would be shown immediately on the thermometer. A valve which will control the level or pressure on the milk flow is easily arranged, but the steam for heating needs considerable attention in order to keep the milk at the proper temperature.

An attempt was made to use the exhaust steam from a 25 H. P. engine for heating the milk. This proved to be no more economical than to take the high pressure steam directly from the boiler. The engine of the creamery is so situated that 60 feet of 2-inch pipe was required to convey the exhaust steam to the pasteurizer, and although this pipe was wrapped with asbestos covering, it was found neccssary to get 3 lbs. back pressure on the exhaust steam in order to warm 3,000 lbs. of milk per hour up to 155° F. Nothing therefore seemed to be gained by taking the steam through the cylinder of the engine instead of a direct connection with the boiler. No difficulty was found in heating the milk up to the required temperature with this machine, when the high pressure steam was used:

The machine can be cleaned easily, and by using a very little care in turning off the heat when the supply of milk stops, the milk does not burn on the hot tin. The pasteurizing apparatus requires more attention to run it, and more labor in cleaning its various parts and extra vats than the apparatus ordinarily used in a creamery for heating milk for separation, but this is because there are more parts to this machine rather than for any other reason. In our experience the milk does not scald on the tin although live steam was used for heating, but the foam which rises on the pasteurized skim milk, especially in hot weather, causes considerable annoyance to the creamery operator, as it is apt to overflow the receiving tank. The milk residue left by this foam is very hard to clean from the tanks or floor, as it sticks very tenaciously when the air escapes from the foam.

II. Results of pasteurizing experiments.

The total number of trials made were 188, of which 78 were under experimental conditions, i. e., the milk was divided into two parts, one of which was pasteurized while the other was made up in the ordinary way. In 110 cases the entire quantity of milk was either pasteurized or unpasteurized, this treatment alternating daily.

In work of this sort, where possible, it is better to divide each lot of milk, pasteurizing one while the other is left as a check. In this way the conditions can be more carefully controlled. The results attained by this experimental method are entitled to more value than where comparisons are made of the churnings of different days.

In the results here presented, the total score is divided into that of flavor and grain, in order that the effect of the pasteurizing process may be better studied.

DISCUSSION OF FLAVOR SCORES OF BUTTER.

Separating the flavor scores on the basis of those which do and do not conform to experimental conditions, i. e., those cases in which the milk was divided and half of it pasteurized, it is evident that there is but little difference as regards the flavor of these two lots. This is shown by the following summary: Class A represents the average score of the butter made on those days when the entire milk supply was either pasteurized or unpasteurized; class B those days when the milk was divided and one part pasteurized while the other was not.

Summary of flavor scores of butter made under experimental conditions and otherwise.

	NORMAL.		PASTEURIZED.	
Size of package.	8 lb.	60 lb.	8 lb.	60 lb.
Class A	40.5 (11 pkgs)	40.7 (48 pkgs)	40.0 (15 pkgs)	41.4 (15 pkgs)
Class B	40.5 (22 ")	40.8 (21 ")	40.4 (22 ")	40.7 (19 ")

Some light is thrown upon the question as to whether pasteurizing improves or impairs the flavor of butter by these scores, which we think are sufficiently numerous to be of some weight on this point. Averaging all the flavor scores of pasteurized and unpasteurized butter shows that the normal product scored only a small fraction of a point higher (40.69 unpasteurized, 40.63 pasteurized), but it should also be noted that somewhat more of the normal butter scored 42 points or higher than that made from the heated milk, as is evident from the following figures:

	Normal.	Pasteurized.
	Per cent.	Per cent.
Butter scoring 42-43 points	18.7	13.9
Butter scoring 40-42 points	67.4	72.3
Butter scoring 37-40 points	13.9	13.8

This difference is however so slight that with the present system of scoring, it is impossible from these results to conclude that one system produces higher flavor than the other. Although but slight numerical differences can be observed between the scores of pasteurized and unpasteurized butter, still the scorer was able in a large number of instances to detect a difference which he designated by various expressions. Referring to pasteurized butter, he frequently used the terms "sweet," "curdy," "flat," "cooked taste," or "tallowy," as expressing certain properties that could not be indicated numerically, while the normal butter was frequently referred to as having a "lively" or "butter taste" showing that he was able to distinguish a difference between the two kinds of butter.

Advocates of this system have claimed that the benefits of pasteurizing were more apparent in some months than others. To note whether any such effect occurs the scores have been arranged according to months.

TABLE 4.—*Average flavor scores of butter made each month.*

MONTH.	NORMAL.		PASTEURIZED.	
	Average score.	No. pack'ges scored.	Average score.	No. pack'ges scored.
February	40.7	6	40.1	5
March	40.8	28	40.7	29
April	41.3	17	41.4	15
May	40.4	23	40.2	6
June	40.4	21	40.0	7
July	40 0	6	39.9	6
	40.69	101	40.63	68

This striking similarity in the average score month by month cannot escape attention. Concerning the gradual rise and fall in the score of either the normal or the pasteurized butter during the season, it is impossible to offer any satisfactory explanation.

DISCUSSION OF SCORES ON GRAIN OF BUTTER.

A comparison of the scores on grain, of the pasteurized and unpasteurized butter, shows that the heating of the milk exerts a marked effect upon the quality of the grain as is seen in the following summary, which presents the relative percentage of total number of samples of each kind of butter.

Score on grain	28	28½	29	29½	30
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Unpasteurized butter	1	7.8	29.4	47.0	14.8
Pasteurized butter	13 7	16.4	44.0	26.4	1.3

Placing the percentage relation on a graphical basis, the following diagram shows the effect of heat on the quality of grain:

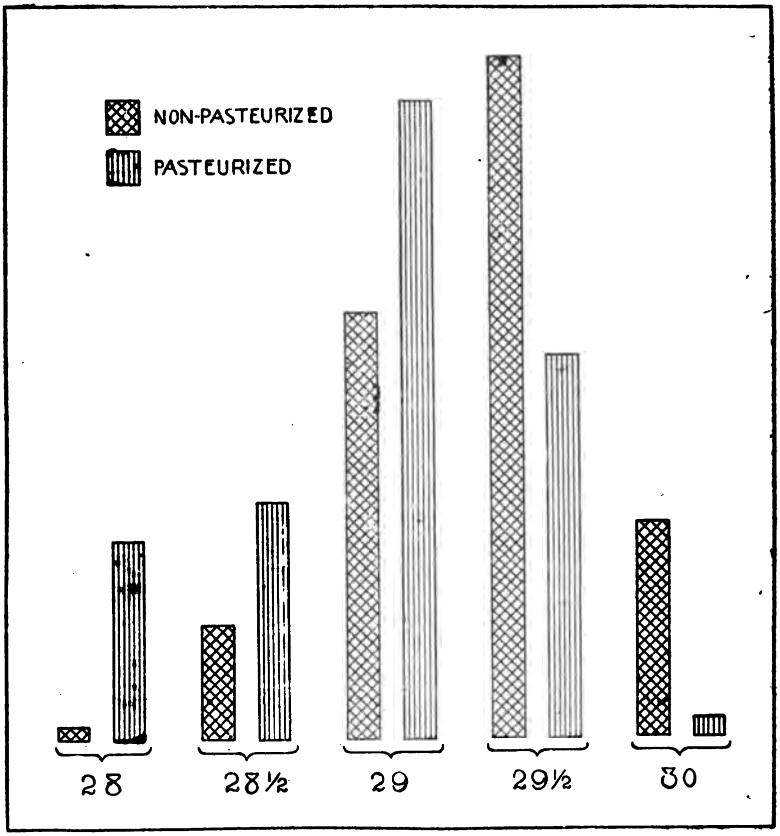

FIG. 11.—Relative score on grain of pasteurized and unpasteurized butter. Perfect grain equal 30 points.

These figures show that only 26 per cent. of the butter from milk skimmed at 155° F. scored above 29 on grain while 62 per cent. of the unpasteurized scored above this figure. The table shows conclusively that heating the milk at this high temperature injured the grain of the butter. The greatest number of perfect scores on grain were reported between May 10th and June 1st when the milk was skimmed without heating it.

Only one package of the pasteurized butter scored perfect, or 30, and ten packages of this butter were given the lowest score, 28. While eleven packages of the unpasteurized butter scored 30 and only one scored 28.

The records show that there was a variation of only one point in the grain scores of 149 of these 175 packages. This seems like a very narrow margin on which to grade butter, especially when an expert makes this difference in scoring two packages of butter from the same churning.

UNIFORMITY OF PRODUCT.

Considering first the flavor scores of the pasteurized and unpasteurized butter, one is impressed with the surprising uniformity of both kinds of butter. Of the total number of packages (175) scored by Mr. Woolverton between February and August, 163 of them, or nearly 90 per cent., scored between 39 and 42, five scored below 39 and seven above 42. This shows a marked degree of uniformity in the butter taken as a whole.

As between the scores of pasteurized and unpasteurized butter the following table gives evidence:

	Unpasteurized	Pasteurized.
Butter scoring between:	Per cent.	Per cent.
37-40	13.9	13.8
40-42	67.4	72.3
42-43	18.7	13.9

This indicates that but slight differences exist between the two kinds of butter, but it must be borne in mind that the normal product of our creamery is extremely uniform, probably much more so than the average of creamery butter considered at large. Therefore, we should not unqualifiedly conclude from this work that pasteurizing does not give a more uniform product as regards flavor.

Concerning the uniformity of score on grain, there are also but very slight differences, although the pasteurizing process does affect the grain to a marked extent.

KEEPING QUALITY.

After the first scoring of the butter in the butter cellar, some of the packages were held from two to four weeks at a temperature of 55–60° F. and then scored again. This second scoring of eighty-one packages was made only on the flavor of the butter.

An average of these scores shows that thirty-nine packages of the unpasteurized butter deteriorated 1.2 points in flavor by keeping it at butter cellar temperatures for two to four weeks, while thirty samples of the pasteurized butter lost only .85 of a point under the same treatment.

This indicates that the butter made from heated milk had better keeping qualities than the ordinary product. Quoting from Mr. Woolverton's letter of March 17, 1898, he says, " Usually I have not been much in favor of pasteurizing cream, but the test that I have just made of these 8 lb. pails that were held in storage shows to me that the pasteurizing appears to help hold the sweetness for two or three weeks probably better than unpasteurized butter."

Under date of July 20, 1898, at the close of this series of experiments, Mr. Woolverton writes: "In reply to your request for any remarks that I may choose to make in regard to the butter I have scored for you during the past season, I would say that while the pasteurized butter has a good, sweet taste, there is not much flavor under the nose, that quick, high flavor that buyers are anxious to find, but I think it has a tendency to hold the butter sweet for a short time, probably fully as well as other ways of making butter."

CHEMICAL COMPOSITION OF THE BUTTER.

The general appearance of the pasteurized butter on the worker, and during the process of its manufacture gives one the impression that it is drier than the ordinary creamery butter. This is so noticeable that the pasteurized butter can often be selected simply by its appearance.

During the progress of this work analyses were made of thirty-three samples of the butter made by the two processes. These analyses included fourteen samples of pasteurized and nineteen of unpasteurized butter. The extreme and average figures obtained by these analyses are given below:

Analysis of Butter from	Fat.	Water.	Curd.	Salt.
Pasteurized milk:	Per cent.	Per cent.	Per cent.	Per cent.
Highest	84.49	14.21	1.68	4.29
Lowest	80.71	11.09	.90	2.32
Average	82.53	13.11	1.22	3.14
Unpasteurized milk:				
Highest	83.57	15.48	2.05	4.68
Lowest	79.22	12.07	1.00	1.91
Average	81.59	13.62	1.29	3.50

These analyses show but very little difference in the composition of the two butters. The average water content of the unpasteurized butter is only .5 per cent. higher than that of the pasteurized butter.

III. Creamery problems in pasteurizing.

The details of pasteurizing present a number of features that differ somewhat from those that usually occur in butter making. Hence, it has been deemed advisable to note some of those that are of especial interest.

SKIMMING.

Clogging of the separator. In these experiments Reid's Improved, Alpha No. 1 and U. S. No. 1 B, separators were used at different times for skimming the pasteurized milk.

No difficulty was found in operating any of these separators during the short time we tried them for skimming milk heated at this high temperature. It was noticed, however, that when old, ripe milk was skimmed, the separator bowls clogged very quickly. In some instances, when the milk was particularly bad, not more than 1,000 lbs. could be skimmed before the separator bowls became choked. At other times when the milk was perfectly sweet, as much as 7,000 lbs. of pasteurized milk could be skimmed without cleaning the separator bowl. It was noticed, however, that more sediment collects in the separator bowl when the milk is skimmed at a temperature of 150° F. than at 85° F. and that the amount of sediment is influenced by the sweetness of the milk.

Capacity of the separator. Heating the milk to a pasteurizing temperature materially increases the amount of milk that a separator will skim clean per hour. In our work it was found that for the amount of pasteurized milk we skimmed per day (3,000–5,000 lbs.), the skimming capacity of the separator was increased about one-half, i. e., if a separator skimmed 2,000 lbs. of 85° F. milk per hour with a test of the skim milk 0.1 per cent. or less, it would skim 3,000 lbs. of milk at a temperature of 155° F. just as well; but if 3,000 lbs. of 85° F. milk was run through the separator per hour, the skim milk tested much higher.

Heating milk with live steam. While carrying on these experiments milk was pasteurized by forcing live steam into it by means of the "Larkey" heater shown in Fig. 10. This or a similar arrangement is ordinarily used in creamery practice for heating milk for ordinary skimming. By opening the steam valve so that sufficient steam was forced into the milk, the milk can easily be heated to 155° F. The skim milk from such a treatment was almost invariably rich, sometimes testing as high as .3–.5 per cent. fat.

The cause of this may possibly be due to the coagulation of albumen by the high pressure steam, while in pasteurizing the milk in the machine, no particle of the milk is subjected to a temperature much above 155° F.

YIELD OF BUTTER.

The yield of butter made from pasteurized cream is slighlty less than where the product is made in the ordinary manner. An average of the percentage "overrun" of the churnings in each month and the number of churnings included in each average is given in the following table:

TABLE 8.—*Average of the "overrun" percentages from pasteurized and unpasteurized butter.*

	Pasteurized.		Unpasteurized.	
	Per cent.	No. of churnings.	Per cent.	No. of churnings.
March	11.0	6	14.3	9
April	13.7	3	14.5	8
May	9.0	1	14.5	15
June	....	....	12.5	14
Aver. & total	11.6	10	14.0	46

These figures show that the average "overrun" of ten churnings of pasteurized cream was 11.6 per cent.; of 46 churnings of unpasteurized cream it was 14.0.

The slightly diminished yield of pasteurized butter is generally attributed to the loss of butter fat in the buttermilk, this by-product usually testing somewhat higher where the milk is pasteurized.

Among the factors which influence the richness of the buttermilk and one which our observations indicate to be of particular importance in making pasteurized butter, is the temperature of churning, i. e., the temperature of the buttermilk when the churning ends. The temperature of pasteurized cream is always higher, even at churning time, than normal cream, and the effect of this higher churning temperature is the cause of the rich buttermilk. An inspection of our records shows that the average test of 57 samples of pasteurized buttermilk made between March and July was .20 per cent. fat and that of 78 samples of unpasteurized buttermilk taken during the same time, .19 per cent. fat. The average churning temperature during this time was 55° F. for both lots. In nearly every case where the churning temperature of either the pasteurized or unpasteurized cream was 60° F., the buttermilk was unusually rich, but these figures indicate that if the pasteurized cream is churned at as low a temperature as the unpasteurized the buttermilk of both lots tests about the same.

The difference between 58° and 60° in the churning temperature seems in our experience to make considerable difference in the richness of the buttermilk. The thirteen July churnings of unpasteurized butter, the average temperature was 58° F. and the average buttermilk test .24 per cent. fat, while in the twelve churnings of pasteurized butter during the same period, the average churning temperature was 60° F. and the average test .46 per cent. fat.

SCORE OF BUTTER AS AFFECTED BY SIZE OF PACKAGE.

E. H. FARRINGTON.

In the course of the experiments reported in the previous article 8 and 60 lb. packages of butter from the same churning were sent to the scorer for examination.

This was done to test the influence of the size of the package on the quality of the butter or on the scorer's judgment of the same.

A 60 lb. tub gives a 12 inch sample on the trier, while that of the smaller package is only about one-third as long. This larger mass enables the inspector to form a more accurate judgment than is possible with a smaller sample.

The table on page 72 gives the figures obtained in making these comparisons:

The difference between the average score as to flavor of 8 and 60 lb. packages is three-fourths of one point (8 lb. package 40.5, 60 lb. package, 41.25) while the average scores of the different packages on grain or body are practically the same, 29.17–29.16. Stated in another from the results of this table may be summarized as follows:

No. of times 60 lb. butter package scored more on flavor	16
No. of times 60 lb. and 8 lb. package scored the same	9
No. of times 60 lb. package scored less	1
	26
No. of times 60 lb. package scored more on grain	6
No. of times 60 lb. and 8 lb. package scored the same	15
No. of times 60 lb. package scored less	5
	26

The fact that the grain of the butter which is judged by the eye was not affected by the size of the package while the flavor which largely is determined by smell was considerably more pronounced in the larger package, scoring from one-half to two points higher, indicates that the size of the package scored exerts an appreciable effect on the scorer's judgment. In fact this difference between large and small packages of the same butter is greater than that which is found in butter made from pasteurized and unpasteurized milk, and the figures illustrate the necessity of a uniform size of package in judging butter especially for experimental purposes.

TABLE 5.—*Effect of size of package on score of butter.*

PACKAGE NO.	FLAVOR.		GRAIN.		FLAVOR. GAIN OR LOSS.	GRAIN. GAIN OR LOSS.
	8 lb.	60 lb.	8 lb.	60 lb.	60 lb.	60 lb.
3	40	41	28	28½	+1	+½
4	41½	42	29½	29	+½	−½
24	39	41	28½	28½	+2	....
32	40	40½	29½	29½	+½	....
39	39½	41	29	29½	+1½	+½
42	41½	41½	29½	29½	....	....
44	41	41	29½	29½	....	....
45	42	42	29½	29½	....	....
46	41½	41	29½	28	−½	−1½
33	40	40½	29½	29	+½	−½
38	39½	41½	29	29½	+2	+½
41	40	40	29½	29½	....	....
43	41	41	29½	29½	....	....
16	40	41	29	29	+1	....
19	40	41½	29½	28½	+1½	−1
21	41	42	29	29½	+1	+½
22	41	41½	29½	29	+½	−½
26	38	40	29	29	+2	....
27	41	42½	28½	29½	+1½	+1
29	40	42	29	29½	+2	+½
30	40	40½	28	28	+½	....
40	41½	41½	29½	29½	....	....
42	41½	41½	29½	29½	....	....
48	41½	41½	29½	29½	....	....
47	40	41½	29	29	+1½	....
76	41½	41½	29½	29½	....	....
Aver. score	40.5	41.25	29.17	29.16		

PROPAGATION OF STARTER FOR RIPENING CREAM.

H. L. RUSSELL.

One of the difficulties with the pure culture system of butter making is that great care must be taken in the propagation of the culture starter in order to insure its purity. When the starter is handled in a commercial manner, it not often happens that everything is kept bacteriologically clean, but the importance of this point is so great that special attention should be paid to this matter.

It is immaterial whether the starter is prepared from a pure culture ferment or from domestic origin, as regards the manner in which it should be propagated.

To secure the best results, even with a home-made starter, it is essential that methods should be followed which conform to bacteriological requirements as strictly as where pure cultures are used.

The method here described was followed in experiments where a pure culture was employed in pasteurized cream.

The apparatus used for this purpose is shown in Fig. 12. Two cans (B) provided with covers are used for the sterilizing and subsequent propagation of the starter. This enables a transfer to be made from one can to another without any unnecessary delay. These are filled with fresh separator skim milk and then sterilized by immersing them in a vat (A) which is filled with water heated by means of steam from pipe (D). The temperature of the skim milk contained therein can be easily raised to 190° F. or thereabouts, and should be maintained for about two hours.

GERM CONTENT OF HEATED MILK.

To test the germ content of the sterilized milk that was used for the propagation of the culture starter, a bacteriological examination was made at frequent intervals. As a result of this, it was found that the bacteria that were able to resist this severe sterilizing operation were extremely few (7–30 organisms per cc.) so that the milk may be considered as practically sterile.

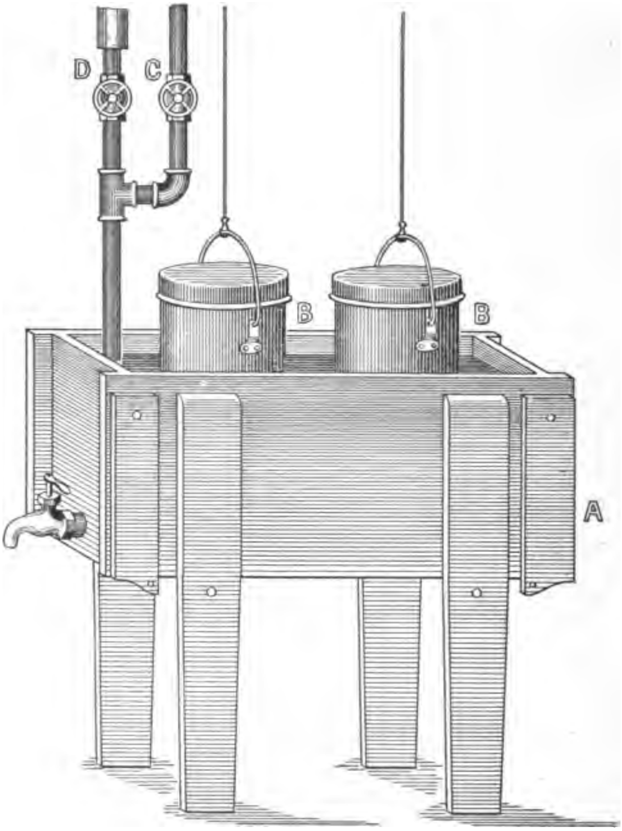

FIG. 12.—Arrangement for sterilizing and propagating starter, A, Water tank; B, Cans in which milk for starter is heated; C, Water pipe; D, Steam pipe.

After the milk is heated it should be cooled down to about 70° F. before adding the pure culture ferment or original starter. Care should be taken not to add the culture to the milk while it is hot, because the germs in the culture might be killed. Sometimes it is advisable to "build up" the culture, making thereby a larger volume before it is added to the sterilized milk. This can be done by incubating the original culture in a smaller volume of milk, and then adding this to the larger mass that is to serve as a starter to be perpetuated.

After the culture is added to the sterilized skim milk, the can (B) may then be immersed in the vat filled with water at 60°-65° F. The large volume of water will hold the temperature for quite a time, and if it falls below this, it can be reheated easily from the steam connection. In this way a fairly constant temperature is easily maintained. Generally the starter so handled curdles in about 20 hours. It is important that the curdling of the starter should not occur much before it is used for two reasons:

First, it is difficult to break up a curd sufficiently fine without passing it through a strainer. If curd particles are incorporated in the butter, they often give the product a mottled aspect (butter with white specks).

Second, the vigor of the starter is undoubtedly stronger when the milk is on the point of curdling than it is after the curd has been formed for some time. The formation of lactic acid tends to kill out the very bacteria that make it, and this effect is accelerated with an increase of acidity.

The starter should be prepared fresh every day, a transfer being made from one can to the other by means of a steamed dipper.

It is interesting to know how long a starter can be propagated without becoming contaminated, and for this purpose, bacteriological examinations were made, but in this instance not with much satisfaction. The difference between the aroma-producing organism of the culture used and the normal lactic acid bacteria was not sufficiently marked when the cultures were grown on gelatin plates to permit of an accurate differentiation. Numerous attempts were made by changing the character of the media, and in other ways, to gain some definite knowledge on this point but with little success. It was determined that the culture organism lived for a considerable time in the starter, but just how long, and the relation which it bears to the indigenous milk organisms could not be definitely proven.

From previous experiments, however, with other lactic organisms that were better differentiated from the normal milk flora, we have determined that a culture of a vigorous growing organism in milk may be kept in a state of comparative purity for several weeks.

CONCLUSION.

The propagation of a starter is a matter of essential importance in butter-making. This process is in all particulars a bacteriological operation, and theoretically, it should be carried on with all of the precision that is required in work done in bacteriological laboratories. Just to the extent that the process under commercial conditions can conform to the principles of bacteriological science just to that extent will uniformity in fermentative action continue.

PROPERTIES OF GALACTASE: A DIGESTIVE FERMENT OF MILK.

S. M. BABCOCK, H. L. RUSSELL AND ALFRED VIVIAN.

In the previous annual report,* reference was made to the discovery of certain inherent enzymes in milk, which we believed at the time were actively concerned in the ripening of cheese. Our studies during the last year have been continued especially along these lines with a view of substantiating our previous results, and determining the qualities and attributes of the enzyme here considered.

A repetition of our former experiments on a much more extended scale have given concordant results, and we believe that in this agent, we have to do with the main cause of the breaking down or peptonization of the casein of the milk in cheese.

Our studies during the last year have been especially concerned with a determination of the characteristics of this ferment, which is allied in some respects to trypsin, the digestive ferment of the pancreas. On account of its presence in milk we propose for this ferment, the name *galactase*.

While as a result of our experiments it cannot be shown that this enzyme has been isolated in a pure condition, still sufficiently concentrated extracts have been obtained, so that a number of its more salient properties have been determined. Concerning these, the following preliminary report is herewith presented.

CHARACTERISTICS OF GALACTASE.

In common with other enzymes of this character that exert a digestive action upon proteid substances, it possesses the property of attaching itself to finely divided particles in suspension. Following this law, one might naturally expect that the enzyme would be separated from the milk, and appear in the cream and separator slime, obtained during the process of centrifugal separation of cream. That this is so, is shown by the fact that the digestive changes occur much more rapidly in cream and separator slime than in whole milk, when such samples are kept under the influence of anaesthetics, which effectually prevent all changes produced by the action of living organisms, whether of bacterial or other origin.

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* 14th Ann. Rept. Wis. Expt. Stat., p. 161, (1897).

Cream, on account of its freedom from foreign matter, would naturally be selected as a source from which to isolate this enzyme were it not for the difficulty of removing the fat from the same. That cream contains more of this proteolytic ferment than milk is shown by the increased rate of peptone formation in milks fortified with cream:

TABLE 1.—*Relation of varying percentages of cream to peptone formation.*

	Total N.	Soluble N. at beginning Expt.	Soluble N. at end of Expt.	Per cent. N. in soluble form at end of Expt.
Skim milk	.52	.045	.12	**23.46**
Skim milk + cream (4 per ct. fat.)	.50	.043	.15	**30.**
Skim milk + cream (19 per ct. fat.)	.44	.04	.19	**43.18**
Skim milk + cream (38 per ct. fat.)	.38	.039	.19	**50.**

In centrifugal slime this difficulty does not obtain to such a degree, but slime under ordinary creamery conditions contains such an amount of bacterial life that the objection may well be raised, that a product derived from such a source might be the result of subsequent bacterial fermentation, rather than of the inherent components of the milk itself.

In order to eliminate this factor, especial pains have been taken to secure slime separated immediately after the milk was drawn, the slime itself being obtained within half an hour from the time it was contained in the udder of the animal. The action of slime under these conditions has been entirely harmonious with those made from material secured from the University Creamery, where a lapse of from three to five hours intervened between the time of milking and the separating of the milk.

In order to secure a concentrated extract, our method has been to allow the slime to macerate for about forty-eight hours in a closed vessel to which chloroform is added in excess. In this preliminary process, the enzyme acts upon the proteids of the slime, causing a partial peptonization of the same, which thereby facilitates the extraction of the enzyme itself. The emulsion thus formed is then filtered. The filtration is much facilitated by dividing the emulsion on a number of filters, care being taken to keep the filtrate saturated with the anæsthetic. These extracts can be used for experiments directly, or the enzyme may be still further purified by adding about 40 per cent. of alcohol to the solution which precipitates a large part of the albuminous matter dissolved. The filtrate from this may be concentrated by evaporation at a temperature under 40° C. without injury to the digestive principle. The usual method of precipitating enzymes from solution with absolute alcohol is not recommended, as the proteolytic action of the product obtained in this way is greatly weakened. The extracts obtained in this way contain a considerable amount of soluble proteids, but still many of the properties of the active digestive principle can be determined with relative accuracy.

This enzyme decomposes hydrogen peroxide rapidly. The reaction is marked in the crude slime, and can be directly observed in milk itself in a short time, but in this latter case the test is greatly facilitated by applying Storch's new method* of determining whether milk has been heated to a temperature exceeding 80° C., this test probably being dependent upon the presence of galactase, the activity of which is destroyed by this temperature. Storch's test is made by adding to the milk a small quantity of a solution of potassium iodide and starch, or better still, paraphenylendiamin, and then a few drops of quite dilute hydrogen peroxide. If the milk has not been heated sufficiently high to destroy the enzyme, a blue color immediately appears.

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* V. Storch, 40th Rept. Copenhagen Expt. Station, Denmark.

EFFECT OF TEMPERATURE ON ACTIVITY OF GALACTASE.

All enzymes resemble organized or living ferments in their relation toward temperature, having a minimum, optimum and maximum point for their action, but above and below this range, their activity is suspended, and, finally at high temperatures, the enzyme is absolutely destroyed. These temperature limits vary somewhat for different enzymes. The optimum of those derived from warm blooded animals approximates blood heat, while the maximum limit is not much in excess of this. As yet we have not determined accurately the limits within which galactase is active, but digestion experiments with milk show that proteolytic changes occur much more rapidly at a temperature from 37–42° C. than above or below this range.

Digestion experiments in milk. The following experiments indicate this. A quantity of milk was boiled to destroy the galactase contained therein, and a determination of soluble nitrogen made. Control samples (A) were then set aside, and to the remainder a considerable portion of slime extract was added. This solution is referred to as solution B. B was then divided into two portions, one of which was acidified to 0.41 per cent. acid to phenolphthalein (neutral to litmus); the reaction of the remaining part was 0.1 per cent. acid to phenolphthalein (faintly alkaline to litmus). The per cent. of nitrogen in soluble form was the same in both acid and alkaline series (0.41 per cent.), and the total nitrogen in B 0.73 per cent. Samples of these two series were then exposed at temperatures ranging from 14° C. to 52° C., a number of samples of A being introduced as controls. In two days the samples of B at 37° and 42° had curdled (the acid series curdling first), but an analysis of these milks at this time showed only a slight increase in soluble nitrogen over samples exposed at 21° C. This indicates that the curdling function is independent of the peptonizing action. After eighteen days, analyses of all samples were made. The following table shows that the optimum activity, as determined by the amount of by-products, occurred at approximately the blood temperature. Samples at 52° C. were quite retarded in their rate of change, and were practically the same as those kept at 28° C. It will be noted that the peptonization of the caesin was more rapid in the alkaline than in the acid series. If the analysis had been made earlier, this difference in soluble nitrogen in the two series at optimum temperatures would undoubtedly have been much more marked. After eighteen days' incubation at this temperature, over 85 per cent. of the total nitrogen in the samples was rendered soluble. Unquestionably the alkaline series reached this point before the other, as its rate of change was considerably more rapid at first.

TABLE 2.— *Effect of temperature on the activity of galactase.*

DATE.	Sample.	Temperature. ° C.	PER CENT. OF NITROGEN IN SOLUBLE FORM IN		
			Acid series.	Alkaline series.	Control.
July 20	Boiled milk = A..........	....	....	....	.05
July 20	A + slime extract = B	....	.41	.41	....
Aug. 8.........	Solution B..............	14	.50	.53	....
Aug. 8.........	Solution B..............	15	.50	....	....
July 22	Solution B..............	21	.47	.52	....
Aug. 8.........	Solution B..............	21	.52	.57	....
Aug. 8...... ...	Solution B..............	28	.53	.60	....
July 22	Solution B..............	37	.48	.56	....
Aug 8.........	Solution B..............	37	.63	.64	....
Aug. 8.........	Solution A..............	37	....	....	.05
Aug. 8.........	Solution B..............	42	.63	.64	....
Aug. 8.........	Solution A..............	42	....	....	.05
Aug. 8.........	Solution B..............	52	.55	....	....
	Total nitrogen in solution B	....	.73	.73	....

The foregoing experiments made to determine the optimum temperature limits show a considerable diminution in activity when the samples were kept at 52° C.

It is important to determine at what temperature the activity of the enzyme is completely lost. Experiments made last year showed that when the milk was heated for fifteen minutes at 65° C. the proteolytic action was quite as marked as in raw milk, but where heated to 97° C. for five minutes no digestion occurred.

To determine the point that with a living ferment would be called its "thermal death point," experiments were made with the following results:

TABLE 3.— *Digestive action of heated enzymes.*

Per cent. of nitrogen in soluble form in original milk	0.05 per cent.
Per cent. of nitrogen in soluble form in milk heated at different temperatures and incubated for fifty-three days at 37° C.	
1. Heated ten minutes at 65° C	.20
2. Heated ten minutes at 71° C	.12
3. Heated ten minutes at 76° C	.05
4. Heated ten minutes at 79°-80° C	.05

All of these milks finally coagulated, the last to change being the sample heated to 80° C. A determination of soluble nitrogen made after this physical change had occurred, showed however, only .05 per cent., indicating that no digestion in samples 3 and 4 had taken place. This again seems to indicate that a curdling enzyme is present in fresh milk that is independent of the digestive change.

From the above it is apparent that heating the enzyme solutions for ten minutes at 76° C. suffices to destroy the digestive ferment galactase, and even at 71° C. for the same exposure its action was materially reduced.

Digestion experiments in gelatin. Fermi has recommended the use of gelatin as a test of the digestive power of proteolytic enzymes. Where we have used this test in studying galactase under favorable conditions, our results have been fairly satisfactory* but where the activity of this enzyme has been impaired by exposing it to an unfavorable environment, the results on gelatin have not been as sharply defined as with milk.

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* 14th Annual Rep. Wis. Expt. Stat., p. 181, 1897.

An enzyme solution made neutral to litmus was divided into four parts, to one of which lactic acid equivalent to a decinormal solution, was added. Two other portions were made alkaline with sodium hydrate to 1-10 and 1-25 normal, and all four were then diluted to the same volume.

Portions of these four series were then heated to 65, 70, 75 and 80° C. for 10, 30 and 60 minutes respectively. These were then tested by Fermi's gelatin method. None of these heated extracts showed any liquefying action on gelatin although exposed for seven weeks. On the other hand, the unheated samples which served as controls all digested the gelatin, the most marked liquefaction occurring in the tubes containing the enzyme extracts neutral to litmus and 1-25 normal alkali.

These gelatin experiments indicate that a reaction neutral or slightly alkaline to litmus is most favorable to the liquefaction of gelatin, and that decinormal solutions of acids and alkali both retard it.

INFLUENCE OF HEAT UPON THE HYDROGEN PEROXIDE TEST FOR GALACTASE.

The decomposition of hydrogen peroxide is frequently given as a test for the presence of unorganized ferments. In our experience it has been found that milk products containing galactase rapidly decompose hydrogen peroxide.

The application of Storch's test, already described, to milk products containing galactase invariably gives a positive reaction. Inasmuch as this test seems to be very sensitive to the presence of this enzyme, it has been employed in determining the effect of heat on solutions containing galactase.

The series of extracts used in the preceding gelatin experiments were also submitted to Storch's test with the following results:

TABLE 4.— *Testing effect of heated galactase solutions upon Storch's test.*

Temperature of heated sample. °C.	Time heated, minutes.	SERIES.			
		1	2	3	4
		$\frac{n}{10}$ NaOH.	$\frac{n}{25}$ NaOH.	Neutral to litmus.	$\frac{n}{10}$ Lactic acid.
65	10	+	+	+	+
	30	+	+	+	+
	60	+	+	+	±
70	10	+	+	+	+
	30	+	+	+	±
	60	+	+	+	—
75	10	+	+	+	±
	30	+	+	+	—
	60	+	+	+	—
80	10	+	+	+	—
	30	+	+	±	—
	60	±	—	—	—

+ = Color reaction.
— = No color reaction.
± = Doubtful reaction.

This table indicates in a striking manner the influence of the chemical reaction, together with the time of exposure to heat upon solutions of galactase. In the neutral and alkaline series, hydrogen peroxide was decomposed in all cases, when the temperature did not exceed 75° C. for 60 minutes, and 80° C. for 10 minutes. This thermal limit for the activity of galactase as measured by Storch's test is somewhat higher than that obtained in his experiments with milk,* but it should be noted that the amount of galactase in our experiment was considerably greater than in his where milk was used, thus making the test probably more sensitive.

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* L. c., p. 42.

EFFECT OF CHEMICAL REACTION ON THE ACTIVITY OF GALACTASE.

In the foregoing table showing the behavior of heated milks towards Storch's test, the effect of the chemical reaction of the solution on the decomposition of hydrogen peroxide is most apparent. In the decinormal acid series, the color reaction failed or was doubtful, where the milks were heated for sixty minutes, and even an exposure for ten minutes at 75° C. also gave uncertain results. The protective effect of alkalies on the activity of the ferment is especially shown in the series heated to 80° C.

This result confirms those obtained last year in digestion experiments with milk which are for convenience reproduced here:

TABLE 5.—*Influence of chemical reaction upon digestion of milk.*

Series.		Per Cent. Total N. in Soluble Form at		Per cent. of total N. digested.
		End of experiment.	Beginning of experiment.	
Neutral	Milk + slime extract neutralized with $Na_2 Co_3$	62.50	36.00	26.50
Acid	Milk + slime ext. + .075 HCl	57.72	36.00	21.72
Strongly acid.	Milk + slime ext. + .15 HCl	47.70	36.00	11.70

Results upon gelatin with neutral and acid extracts of galactase also showed a more rapid liquefaction in the tube containing the neutral extract.

The above results show that the activity of galactase is materially retarded in the presence of acid and especially hydrochloric acid. This indicates the relation of the enzyme to the tryptic rather than the peptic type of ferments.

ACTION OF CHEMICAL SUBSTANCES.

Strong disinfectants such as mercuric chloride, formalin, phenol and its derivatives, and carbon bisulfide destroy this enzyme, as is evidenced from the fact that milks are preserved indefinitely by these reagents. Of the considerable number of substances recommended by different investigators, as inhibiting bacterial activity without repressing the action of unorganized ferments, the larger proportion have been found inadequate to suppress bacterial growth in milk. Chloroform, ether, toluol and benzol act as efficient antiseptics in milk, and still permit enzyme activity. Strong solutions of these agents however retard this digestive action. Where antiseptics that combine with the butter fat are used, larger amounts must be employed to suppress vital activity. On account of its specific gravity, and its emulsive power with fat, chloroform has proved the best agent in this work, two or three per cent. being sufficient to keep milk from souring.

DECOMPOSITION PRODUCTS FORMED BY GALACTASE.

Milks which have been subjected to the action of galactase for a considerable time show a decomposition of the protein in all stages ranging from albumoses to ammonia. Within a short period, ammonia appears in conjunction with amido acids (tyrosin and leucin) and other intermediate products. These by-products are similar to those formed in tryptic digestion and shows the tryptic-like character of this ferment.

The above decomposition products are identical with those that appear in a well ripened cheese and furnish analogical evidence of the rôle which this ferment plays in this process.

DISTRIBUTION OF GALACTASE IN COW'S MILK.

S. M. BABCOCK, H. L. RUSSELL AND ALFRED VIVIAN.

Our previous studies having demonstrated the presence of galactase in cows' milk, attempt was then made to determine its distribution at different periods of lactation and also the quantity present in individual milks taken at same period of lactation.

DISTRIBUTION AT DIFFERENT PERIODS OF LACTATION.

If this enzyme is associated with the maternal function, it seemed probable that it might be present in larger amounts in the earlier stages of lactation. To ascertain if this were so, milks from five different cows were analyzed at stated periods of lactation. The results of these analyses are found in the subjoined table. In addition to these milks, two instances are cited where the lactation period was extraordinarily prolonged.

From this table it will be seen that a quantitative estimation of the enzyme, measured by the amount of soluble proteids formed, shows but little difference during the advancing period of lactation, the milks taken at different periods varying in no regular manner. Even in cases where the milk was from cows that had been milked for nearly two years, the rate of conversion of proteids was not essentially different from the earlier stages of lactation.

TABLE 6.— *Progressive digestion of nitrogen constituents in cows' milk at different periods of lactation.*

Number of cow.	Date of sample.	Period of lactation in days.	Laboratory No.	Acidity.	Per cent. nitrogen in milk.	FRESH.		7 DAYS.		14 DAYS.		1 MO.		2 MO.		6 MO.	
						Per cent. soluble N.	Per cent. total N. in sol. form.	Per cent. soluble nitrogen.	Per cent. total N. in sol. form.	Per cent. soluble nitrogen.	Per cent. total N. in sol. form.	Per cent. soluble nitrogen.	Per cent. total N. in sol. form.	Per cent. soluble nitrogen.	Per cent. total N. in sol. form.	Per cent. soluble nitrogen.	Per cent. total N. in sol. form.
I.	10-29-97	5	48	.18	.56	.05	9.10	....	......	.12	21.42	.15	26.78	.19	33.92	.22	39.28
	11-19-97	26	55	.18	.45	.04	8.88	.10	22 22	.14	31.11	.15	33.33	.17	37.77	.19	42.22
	12-20-97	56	76	.18	.50	.04	8.00	.09	18.00	.12	24.00	.17	34.00	.19	38.00	.25	50.00
	1-20-98	87	88	.16	.46	.05	10.86	....	......	....	......	.15	32.60	......	......	....	....
	4-20-98	184	109	.14	.45	.04	8.88	....	......	...	......	....	......	......	......	....	....
II.	12-17-97	5	75	.15	.68	.08	8.82	.10	14.70	.12	17.64	.15	22.05	......	......	.28	41.17
	1-6-98	25	85	.17	.50	.05	10.00	.06	12.00	.07	14.00	.10	20.00	......	......	.22	44.00
	2-7-98	56	95	.15	.55	.04	7.27	....	......	....	......	....	......	......	......	....	....
III.	12-31-97	5	80	.16	.67	.08	11.94	.09	13.43	10	14.92	....	......	......	......	.25	37.31
	1-20-98	25	89	.15	.48	.04	8.33	....	......	....	......	....	......	......	......	....	....
	2-21-98	57	98	.17	.50	.04	8.00	....	......	....	......	....	.....	......	......	....	....
	3-21-98	85	104	.14	.45	.04	8.88	....	......	....	......	...	... ..	......	......	....	....
IV.	1-3-98	5	82	.18	.62	.05	8.06	.06	9.67	....	......	....	......	......	......	.25	40.32
	1-24-98	25	90	.16	.45	.04	8.88	....	......	....	......	....	......	......	......	....	....
	2-24-98	56	99	.15	.50	.04	8.00	....	.. ..	....	......	....	......	......	......	....	....
	3-24-98	84	105	.14	.45	.04	8.88	....	......	....	......	....	......	......	......	....	....
V.	1-13-98	5	87	.16	.60	.06	10.00	....	......	.08	13.33	.10	16.66	......	......	.25	....
	2-3-98	25	93	.14	.43	.04	9.30	....	......	....	......	....	......	......	......	.19	....
	3-3-98	53	100	.14	.45	.04	8.88	....	......	....	......	....	......	......	......	....	....
	4-2-98	95	106	.16	.43	.04	9.30	....	......	....	......	....	......	......	......	....	....
	7-7-98	185	115	.13	....	.04	......	....	.... .	....	.....	....	......	......	......	....	....
VI.	11-30-97	605	61	.13	.62	.05	8.06	.06	9.67	.05	12.90	.12	19.35	......	......	.16	25.48
VII.	1-3-98	725	84	.15	.58	.05	8.58	....	......	....	......	.13	22.41	......	... ..	.25	41.27

During the colostrum period, the amount of soluble proteids seems to be slightly increased at the beginning, when compared with the normal milk of the same animal five days after calving, as is seen in the following table:

Table 7.— *Comparative rate of digestion of colostrum and milk taken five days after calving.*

No of Cow.	Per cent. of Nitrogen in Soluble form in							
	Colostrum milk.				*Normal milk.*			
	Fresh.	14 days.	1 mo.	6 mo.	Fresh.	14 days.	1 mo.	6 mo.
I.........	.09	.15	.21	.44	.05	.12	.15	.22
II........	.07	.09	.16	.43	.06	.12	.15	.28
III.......	.10	.12	.15	.53	.08	.10	....	.25
IV........	.07	.08	.11	.30	.06	.08	.10	.25
V	.07	.10	.12	.25	.05	.07	....	.23
Av......	.08	....	....	.39	.06	....	....	.25

This slight initial difference in amount of soluble proteids becomes more marked as the age of the sample increases. The average of five colostrum milks six months old is 0.39 per cent. of soluble nitrogen, while that of fresh normal milk from same animals kept under identically the same conditions is only 0.25 per cent., showing a marked increase in the rate of digestion of the proteids in the colostrum milk. Whether this increase is to be associated with the maternal function, or is due to the larger amount of proteids in the colostrum is a question to which our present knowledge gives no satisfactory answer.

DISTRIBUTION IN INDIVIDUAL MILKS AT SAME PERIOD OF LACTATION.

In order to determine whether any uniformity exists in the amount of enzymes present in cows' milk, the milk of a number of animals was subjected to chemical analysis. To render conditions as uniform as possible, samples were taken at the same period of lactation, the age chosen being twenty-five days from calving. Samples were collected directly in bottles containing 5 per cent. chloroform and an initial analysis made on the same day to determine per cent. of total nitrogen, also the amount of nitrogen that was present in soluble form.

The table on opposite page gives the chemical data that indicates the progressive decomposition of the nitrogenous constituents of the milk.

The interpretation of the above data is facilitated by reducing the results to graphical form as in Fig. 13.

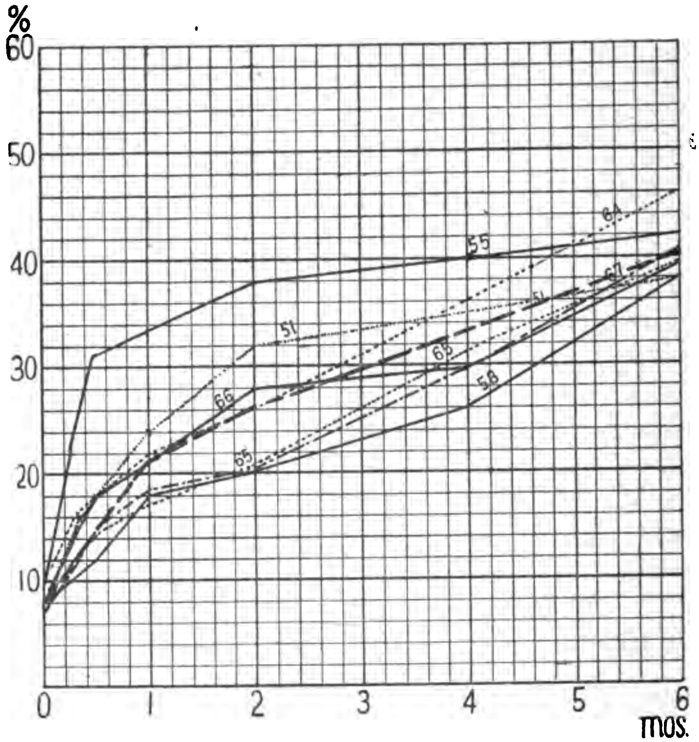

FIG. 13.—Rate of digestion of proteids in individual milks from same period of lactation. Figures indicate laboratory number of sample. Average curve of digestion shown by heavy broken line.

TABLE 8.—*Progressive digestion of nitrogen constituents in milk of different cows at same period of lactation.*

Laboratory number.	Date of collection of sample.	Per cent. of acidity	Per cent. of total nitrogen.	AGE OF MILK WHEN ANALYZED.													
				Fresh.		*1 week.*		*2 weeks.*		*1 month.*		*2 months.*		*4 months.*		*6 months.*	
				Per cent. of sol. N. (Albumen, Peptone, etc.)	Per cent. total nitrogen in soluble form.	Per cent. soluble nitrogen.	Per cent. total nitrogen in soluble form.	Per cent. soluble nitrogen.	Per cent. total nitrogen in soluble form.	Per cent. soluble nitrogen.	Per cent. total nitrogen in soluble form.	Per cent. soluble nitrogen.	Per cent. total nitrogen in soluble form.	Per cent. soluble nitrogen.	Per cent. total nitrogen in soluble form.	Per cent. soluble nitrogen.	Per cent. total nitrogen in soluble form.
51......	11- 4-97	0.17	0.50	0.04	8.00	0.08	16.00	0.09	18.00	0.12	24.00	0.16	32.00	....	....	0.19	38.00
55......	11-19-97	0.18	0.45	0.04	8.89	0.10	22.22	0.14	31.11	0.15	33.33	0.17	37.77	....	....	0.19	42.22
58......	11-22-97	0.16	0.50	0.04	8.00	0.05	10.00	0.06	12.00	0.09	18.00	0.10	20.00	0.13	26.00	0.19	38.00
64......	12- 4-97	0.14	0.50	0.05	10.00	0.08	16.00	0.09	18.00	0.11	22.00	0.13	26.00	....	....	0.23	46.00
65......	12- 6-97	0.13	0.48	0.04	8.33	0.06	12.50	0.07	14.58	0.08	16.66	0.10	20.83	0.15	31.25	0.19	39.58
66......	12- 6-97	0.15	0.61	0.05	8.19	0.09	14.75	0.11	18.03	0.13	21.31	0.17	27.87	0.18	29.50	0.24	39.34
67......	12- 6-97	0.15	0.54	0.04	7.40	0.06	11.11	0.08	14.81	0.10	18.51	0.11	20.37	0.16	29.63	0.22	40.74

The progressive formation of soluble nitrogenous compounds as the milks increase in age is strikingly apparent. When fresh milk is examined, the amount of nitrogen in soluble form, including albumen, peptones, amides, etc., is quite constant, ranging from .04–.05 per cent. or from 8–10 per cent. of the total nitrogen present. Although samples were kept at approximately uniform temperatures, except for seasonal changes, it is very evident that the rate of proteolytic change was much more rapid during the first month than later, the amount of soluble nitrogen being increased from two to three times during the first month, while the increase thereafter was relatively much slower. The slight increase in rate of decomposition that occurs in some of the samples analyzed at four and six months period is undoubtedly due to the accelerated action of the enzyme caused by the rise of temperature during the months of May and June. This view is confirmed by the fact that milks designated by laboratory numbers 51 and 55, the analyses of which had been completed before the summer season began, conform more nearly to the theoretically progressive curve due to enzyme action.

The curves formed by plotting these respective analyses show the same general character. The curve formed by averaging the individual results agrees quite closely with that which represents the curve of enzyme action.

While some variation exists in the amount of nitrogenous elements decomposed, still in milk taken from different cows at the same period of lactation, a surprising similarity in the amount of nitrogen converted into soluble form is to be observed.

DISTRIBUTION OF GALACTASE IN DIFFERENT SPECIES OF MAMMALIA.

S. M. BABCOCK, H. L. RUSSELL AND ALFRED VIVIAN.

The discovery of the fact that cow's milk contains a proteolytic ferment naturally led to the question whether this enzyme is present in the milk of other species of mammalia. To ascertain whether this was so, we have endeavored to secure milk from as large a number of animals as possible, and to subject them to the same tests employed in our studies of cow's milk.

We have only been able to secure milk from a comparatively few species of animals, although strenuous efforts were made to obtain milk from other than herbivorous species.

In this connection we desire to acknowledge our indebtedness to the Office of Experiment Stations, United States Department of Agriculture, Prof. John Weinzirl, University of New Mexico, Albuquerque, N. M., Mr. J. H. Edwards, Kalispell, Mont., Huber Brothers, Cochrane, Wis., Dr, L. R. Head, Madison, Wis., and various museums and zoological gardens throughout the country.

The samples in all cases were preserved in chloroform from the beginning, and were subjected to chemical analysis at stated intervals, to determine the amount of proteids rendered soluble by the action of the ferment. In the case of sow's milk, it should be borne in mind that the results may be influenced by the fact that the milk represents only a portion of the secretion, it being impossible to secure a sample except when the young were suckling. In the following table only the cow's and goat's milk represent composite samples. Table 9, shows the analytical data gathered in the course of this work.

TABLE 9.—*Proteolytic changes in milks from different species of mammalia.*

Date of Sample.	Kind of milk.	Lab. No.	Total Nitrogen.	Age of Milk when Analyzed.									
				Fresh.		*1 mo.*		*4 mo.*		*5 mo.*		*6 mo.*	
				Pr ct. soluble N.	Pr ct. total N. in soluble form.	Pr ct. soluble N.	Pr ct. total n. in soluble form.	Pr ct. soluble N	Pr ct. total N. in soluble form.	Pr ct. soluble N.	Pr ct. total N. in soluble form.	Pr ct. soluble N.	Pr ct. total N. in soluble form.
12- 4-97..	Sheep	69	.76	.09	11.84	.15	19.73	......	......	......	......	......	......
12- 4-97..	Sheep	70	.71	.10	14.08	.17	23.94	......	......	......	......	......	......
12- 4-97..	Sheep	71	.60	.10	16.66	.15	25.00	.18	30.00	......	......	.27	45.00
12- 4-97..	Sheep	72	.76	.09	11.84	.14	18.42	.17	22.37	......	......	.28	36.84
12-29-97..	Sheep	78	.80	.10	12.50	.12	15.00	.17	21.25	......	......	.28	35.00
12-13-97..	Human ..	74	.28	.10	35.71	.13	46.43	.14	50.00	......	.....	.15	53.57
2- 1-98..	Human ..	92	.28	.10	35.71	......	......	.14	50.00	......	......	.14	50.00
3- 8-98..	Human ..	101	.27	.10	37.03	......	......	.12	44.44	......	......	.14	51.85
5- 2-98..	Human ..	112	.27	.09	33.33	.11	40.74	......	......	......	......	......	......
6-23-98..	Human ..	113	.28	.10	35.71	......	......	......	......	......	......	.....	......
7- 1-98..	Human ..	114	.27	.10	37.03	......	......	......	......	....	......	......	......
2-21-98.	Goat	97	.78	.06	7.69	.16	20.51	.25	32.05	......	......	.37	47.56
3- 8-98..	Goat	103	.68	....	......	.21	30.88	.32	47.06	......	.....	.38	55.88
4-20-98..	Pig.......	110	.72	.17	23.61	.22	30.55	......	......	.51	71.25	......	......
4-28-98..	Pig.......	111	.70	.16	22.86	.30	42.86	......	......	.49	70.00	......	......
12-29-97..	Mare	83	.28	.09	32.14	.11	39.28	......	......	......	......	.15	53.37
2-21-98..	Burro	96	.25	.10	40.00	.13	52.00	......	......	......	.. ...	.15	60.00
3- 8-98..	Half br'ed buffalo..	102	.48	.04	8.33	......	......	.10	20.83	......	......	.14	29.17
	Cow......	......	.51	.04	8.40	.11	21.57	.16	29.09	......	......	.21	40.55

In order to show the relative changes in nitrogenous constituents of this milk, the foregoing data is presented in graphical form.

Fig. 14 shows the percent. of soluble nitrogenous products in the various kinds of milks.

Fig. 15 indicates the per cent. of total nitrogen in soluble form. These results show that the presence of a proteolytic ferment is not confined to cow's milk, but is found in the milk of all species of animals which we have examined.

Further than this it is impossible to interpret the above data in a satisfactory way from the limited number of analyses that have been made.

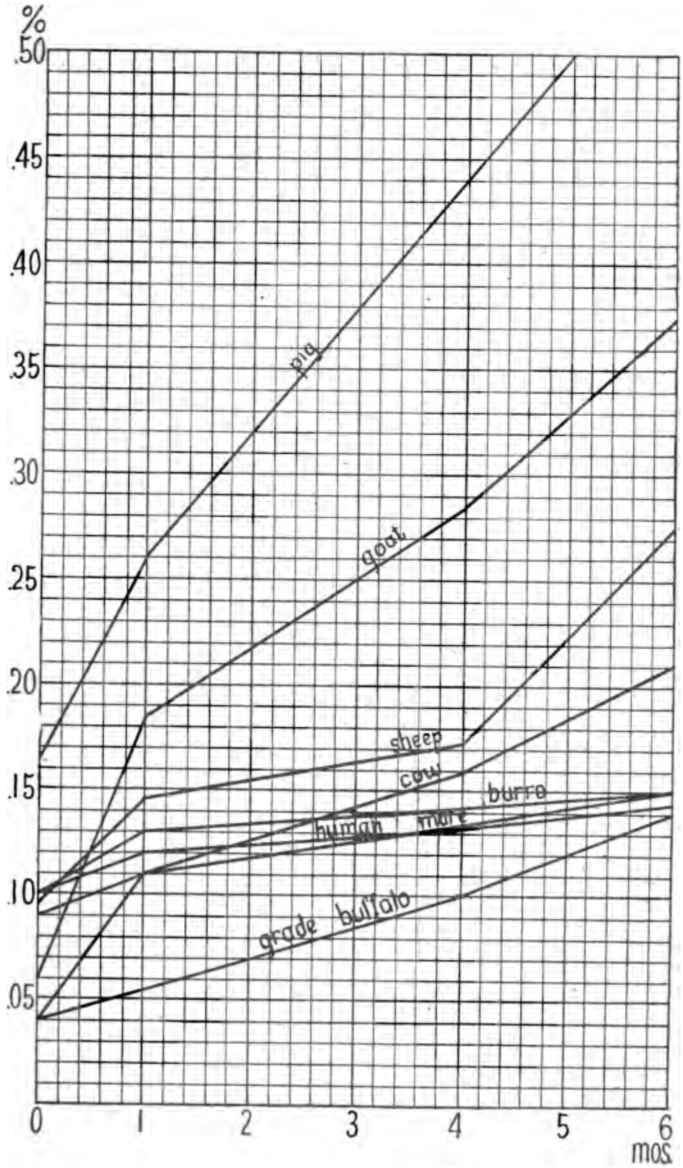

FIG. 14.—Rate of proteid decomposition in milks of different species of mammalia.

Whether the difference in initial amounts of soluble nitrogen, and the varying rates of digestion have any particular significance or not is yet a question. The milk of different species of animals varies so materially in its chemical composition, in its chemical reaction, etc., that it is impossible to secure uniform conditions under which the ferment could act.

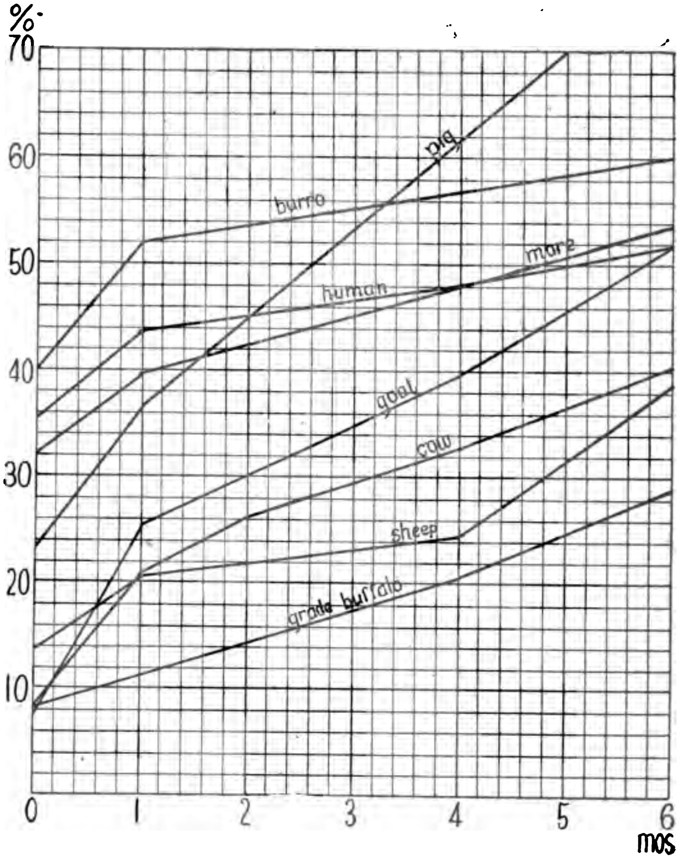

FIG. 15.—Per cent. of total N. digested in milks of different species of mammalia.

The results in the preceding paper (page 89) on the relative digestion of colostrum and normal milks might be construed as indicating that the presence of this ferment varied with the amount of proteids in the milk. If we compare the milks of different animals with that point in view, it is evident that no such relationship can be maintained. On the supposition that this ferment action might have some relation to the maternal function, it was thought possible that animals in which the milk-producing tendency had not been abnormally developed by selection might contain larger quantities of this ferment. A study of the above table and figures shows, however, that no such conclusion can be drawn.

THE ANTISEPTIC VALUE OF CERTAIN CHEMICALS IN MILK.

S. M. BABCOCK, H. L. RUSSELL AND ALFRED VIVIAN.

Unorganized ferments or enzymes are formed as a result of the protoplasmic activity of the animal or vegetable cell. This activity of animal or vegetable protoplasm is inhibited in the presence of many chemical agents. Those substances that act most powerfully in this regard, or which destroy living protoplasm, are called disinfectants; those which merely suspend the activity of the same are known as antiseptics. Some chemical substances which belong to the former class, and a number of those of the latter group, possess the peculiar relation of acting upon living protoplasm, while they do not materially interfere with the unorganized ferments or enzymes that may have been formed by the vital activity of living cells. Among the substances that are said to possess this differential function may be mentioned ether, chloroform, thymol, benzol, toluol, salicylic acid, boracic acid, arsenious acid, sodium fluoride and several essential oils.*

This valuable property is taken advantage of in distinguishing between the activity of living ferments and enzymes derived from cellular activity. Early in our studies upon the presence of enzymes in milk, we became convinced that the action of a number of these substances did not conform with the statements made. Inasmuch as the disinfecting action when used in milk was always less than that given in the literature, it appeared that the character of the menstruum exerted a marked effect upon the disinfecting action of the chemical used. Experiments were therefore made, by adding to milk, various quantities of a number of antiseptic substances that would not repress enzyme action.

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* Neumeister, Lehrbuch der physiologischen Chemie, p. 98. Bourquelot, Les ferments solubles.

In the following table, data are shown that indicate not only the keeping quality of the milk treated with these various chemicals, but also the time of curdling of the milk induced by the action of the inherent enzyme, and the amount of soluble nitrogenous products found in the course of thirty days as a result of the protracted action of these ferments. Two series of experiments were made. In the first series, the acidity of the milk was 0.08 per cent.; in series two the acidity was 0.11 per cent.

In connection with this table, the approximate germicidal effect of each chemical tested is also given.

Table 10.— *Antiseptic effect of different substances on milk and the amount of soluble N. compounds formed.*

Antiseptic used.	Percentage Strength of antiseptic.	Time of souring in days.	Time of curdling due to enzyme.	Per cent. of soluble N. found in 30 days.	Reputed antiseptic value of reagent used.
Benzol.					
1st series..........	3	14	....	....	Twenty days exposure failed to kill anthrax spores (Koch.)
	5	....	26	.187	
	7	....	26	.185	
	10	....	26	.184	
2nd series.........	2	9	....	....	
	3	....	20	.23	
	5	....	20	.22	
Chloroform.					
1st series..........	5	....	26	.23	No effect on anthrax spores — kills vegetating bacteria easily. One per cent. solution destroys cholera in one min. Used to sterilize blood serum.
	8	....	26	.23	
	10	....	26	.21	
	12	....	26	.19	
2nd series.........	2	....	20	.25	
	3	....	20	.25	
	5	....	20	.23	
Ether.					
1st series..........	5	11	....	....	Anthrax spores not destroyed in 8 days but killed in 30 days (Koch). Tubercle bacillus killed in ten min. (Yersin.)
	8	....	45	.23	
	10	....	45	.247	
	15	....	45	.248	
	20	....	over 45	.231	

TABLE 10.—*Antiseptic effect of different substances upon milk and the amount of soluble N. compounds formed* —continued.

Antiseptic used.	Percentage Strength of antiseptic.	Time of scouring in days.	Time of curdling due to enzyme.	Per cent. of soluble N. found in 30 days.	Reputed antiseptic value of reagent used.
Toluol.					
1st series..........	3	11	....	....	Used in connection with ferric chloride and alcohol in diphtheria disinfection (Loeffler).
	5	....	27	.20	
	7	....	27	.20	
	10	....	27	.196	
Xylol.					
1st series..........	3	1	....	....	
	5	1	....	....	
	7	1	....	....	
	10	1	....	....	
Aniline.					
1st series..........	0.05	1	....	....	Antiseptic 1:5 (Riedlin.)
	0.25	1	....	....	
	0.5	3	....	....	
Arsenious Acid.					
1st series..........	0.1	2	....	....	Antiseptic in 1:166 (Miquel). 1 per cent. destroys anthrax spores in 10 days (Koch).
	0.4	2	....	....	
	0.7	2	....	....	
	1.0	3	....	....	
	2.0	3	....	....	
Oil Origanum.					
2nd series.........	0.5	1	....	....	Powerfully antiseptic (Chamberland).
	1.5	1	....	....	
	3.0	2	....	....	
Thymol.					
1st series..........	0.25	3	....	....	Development of anthrax spores retarded in 1:80000 (Koch). Tubercle bacillus destroyed in 3 hours (Yersin). One-fourth as strong germicidal effect as carbolic acid (Behring). Antiseptic in 1:1340 (Miquel).
	0.5	10	....	....	
Sodium Fluoride.					
1st series..........	0.5	15	....	....	
	1.0	a	....	....	
	2.0	....	b	.14	
	4.0	....	b	.12	
Phenol.					
2nd series.........	0.25	3	....	....	Begins to act antiseptically 1:1250; inhibits growth at 1;850; disinfects at 1:400-200; spores killed 1-2 days in 5 per cent. solution.
	0.5	13	....	....	
	2.5	13	....	....	

TABLE 10.—*Antiseptic effect of different substances on milk and the amount of soluble N. compounds formed.*— Continued.

Antiseptic used.	Percentage Strength of antiseptic.	Time of souring in days.	Time of curdling due to enzyme.	Per cent. of soluble N. found in 30 days.	Reputed antiseptic value of reagent used.
Phenol + ½ per cent. NaCl.					
2nd series..........	0.25	5	....	....	Antiseptic action much intensified by addition of salt Scheurlen).
	0.5	....	Over 20	.18	
	2.5	....	b	.04	
Oil Cloves.					
1st series..........	0.25	1	....	....	Riedlin reports clove oil as having high antiseptic properties.
	0.375	2	....	....	
	0.5	3	....	....	
	0.66	6	....	....	
	1.0	10	....	....	
Oil Cassia.					
1st series..........	0.05	1	....	....	
	0.25	6	....	....	
	0.375	10	....	....	
	0.5	14	....	....	
	0.25	....	b	.12	
Oil Ceylon Cinnamon.					
1st series..........	0.1	2	....	....	One of the most powerful germicides among the essential oils (Chamberland). Compared with phenol, its action is 3 times as powerful (Behring). Kills typhoid bacillus in 12 min. (Cadeac & Meunier).
	0.2	2	....	....	
	0 5	6	....	....	
	1.0	20	....	....	
	2.0	....	b	.15	
Turpentine.					
2nd series	0.1	1	....	....	Retards growth in 1:75-000 (Koch). Spores live 1 day but succumb in 5 days (Koch).
	0.2	1	....	....	
	1.0	1	....	....	
Oil Mustard.					
2nd series	0.01	2	....	....	Exerts some antiseptic action in 1:330000; inhibits growth of anthrax spores in 1:33000 (Koch).
	0.02	2	....	....	
	0.04	5	....	....	
	0.06	7	....	....	
	0.2	13	....	....	

a Did not coagulate but showed .36 per cent. acidity in 30 days.

b Did not coagulate in 30 days but acidity remained unchanged.

From the above table, it is evident that there is a marked discrepancy between the ability of these substances to prevent bacterial changes in milk, and their reputed efficiency as antiseptics. It has been our experience that it is entirely unsafe to rely upon the preservative action of any chemical of this class in milk when used in the proportions that are said to be effective. Our early experiments with cream showed that it required a very much larger amount to prevent bacterial changes than was necessary in normal milk.

The marked discrepancy that exists between the action of these substances in milk and other fluids can undoubtedly be explained on the theory that they form insoluble compounds with the butter fat, and therefore, their antiseptic property is greatly diminished.

The following experiment throws light upon this point:

TABLE 11.—*Effect of butter fat on antiseptic efficiency of benzol.*

	Amount of benzol added to milk or cream.						Per cent. fat in milk.
	3 per ct.	5 per ct.	7 per ct.	10 per ct.	20 per ct.	30 per ct.	
Time in days before souring occurred	14	0*	0	0	0	0	4 per cent. whole milk
	....	....	....	1	5	13	40 per cent. cream.

*0=milk did not sour.

This hypothesis is still further supported by the following experiment in which ten per cent. of olive oil was added to to tubes of bouillion, infected with bacterial cultures, to which various quantities of essential oils (Ceylon cinnamon and cloves) had been added.

TABLE 12.—*Effect of olive oil on the antiseptic efficiency of essential oils.*

	Proportion of antiseptic used.					
	1:47	1:78	1:235	1:53	1:107	1:215
Oil cloves....................	—	—	+	....	....	....
Oil cloves + 10 p. ct. olive oil	+ +	+ +	+ +	....	....	....
Oil Ceylon cinnamon.........	....	....	....	—	—	—
Oil Ceylon cinnamon + 10 per cent. olive oil..........	....	....	....	+	+ +	+ +

+ = slight growth.
+ + = copious growth.
— = no growth.

The conclusion is warranted from the above experiments that the antiseptic efficiency of many chemicals is not nearly as marked with milk as with other fluids that do not contain substances like fat, which combines with the antiseptic, and thereby diminishes its efficiency.

Of the number of different chemicals tested, only four, viz., chloroform, ether, benzol and toluol are to be recommended in studying these inherent enzymes.

With these four antiseptics, distinction should be made between the curdling and the proteolytic action. Ether retards the curdling of milk, while scarcely any difference exists in the time of curdling with the other three antiseptics. This effect alone suggested to us the possibility of a curdling enzyme in milk that was different from the digesting ferment.

All of these substances undoubtedly exert some repressing action on the proteolytic changes. Small increments in the amount of antiseptics employed, indicates, almost without exception, that a retardation in the rate of digestion took place. This is especially marked in the case of chloroform where a variation from five to twelve per cent. diminished the amount of soluble products seventeen per cent. Chloroform and ether seem to affect the digestive changes least of all. Chloroform is undoubtenly the best agent for work upon this enzyme as two to three per cent. keeps milk perfectly. Also, on account of its high specific gravity, and its affinity for fat, the cream is thereby submerged, thus rendering possible more accurate sampling.

RELATIVE ABSORPTION OF ODORS IN WARM AND COLD MILK.

H. L. RUSSELL.

It is quite commonly believed by many dairymen that milk will not absorb odors when it is warmer than the surrounding air; that under these conditions, it gives off the "animal odors" with which it may be impregnated. Sometimes this belief is put as follows: Milk evolves odors when warmer and absorbs them only when colder than air temperature. This traditionary belief is sometimes cited as justification of the method that is too frequently practiced of allowing the milk to remain in the barn during and subsequent to the milking process, the claim being made that the rising air currents from the warm milk prevent not only direct absorption but bacterial life from falling into the same. This custom is to be deprecated upon purely bacteriological grounds, inasmuch, as a very considerable number of bacteria are thus introduced directly into the milk, by being deposited upon the strainer cloths, and then washed through the same when pail after pail of milk is strained.

In the course of some experimental work in another connection, the incidental observation was made that warm milk seemed to absorb odors more rapidly than cold. As this result was not in harmony with current beliefs on this matter, it was further tested in the following way: A large box with a tight-fitting cover was taken and in the bottom of the same were placed two jars, one filled with warm water, and the other with ice or cold water. On the surface of each receptacle was then placed a basin filled with milk. The relatively large body of warm and cold water maintained the respective milk samples at temperatures above and below that of the surrounding air. In the bottom of the box was then placed samples of various substances that were to be tested as to their odor-yielding properties. In passing judgment on the relative absorption of odors, the samples of milk that had been exposed, were placed in glass bottles and then brought to the same temperature, care being taken to thoroughly mix the samples so that no physical difference could be detected that would enable the scorers to recognize the respective samples as they tested them from day to day. It was noticeable in this work, that the judgment of the two scorers coincided more closely after the first week's experience. This shows the necessity of continuing such tests over a relatively long period of time and with the same judges, in order to diminish the personal equation which of necessity interferes with results obtained in this way. A number of tests made on successive days, indicated that the milk kept at approximately the body temperature absorbed odors to which it was exposed much more readily than did cold milk.

The following trials were then made under my direction by my assistant, Mr. H. A. Harding.

TABLE 1 — *Relative absorption of odors in warm and cold milk.*

KIND OF ODOR.	Time of exposure.	No. of tests made.	NO. OF TESTS WITH STRONGER ODOR IN Warm milk.	NO. OF TESTS WITH STRONGER ODOR IN Cold milk.
Corn silage	1 hr.	5	5	....
	3 hrs.	3	2	1
	5 hrs.	2	2	....
Horse manure	¼ hr.	3	1	....
	1 hr.	3	2	....
	1½ hrs.	2	1	....
	2 hrs.	2	2	....
Oil of cinnamon	1 hr.	6	5	....
	2½ hrs.	2	2	....
	3 hrs.	3	3	....

In these experiments silage and manure were used as these are the substances that are most likely to cause trouble in the barns. Almost without exception, the samples of warm milk were more strongly impregnated with the odor of these substances than milk which was at a lower temperature than the air. In these experiments, the milk used was from the general creamery supply. The objection might be urged that the conditions did not conform to those of practice, inasmuch, as the warm milk direct from the animal might not act in the same way as that which had been heated up after once being cooled. To meet this possible objection, another set of experiments was instituted, the details of which were performed by one of my special students, Mr. Wm. Dietrich.

In this series, the milk was drawn from the animal, and immediately submitted to the influence of different odors in a manner as before. For these experiments, a number of the volatile essential oils were chosen, as they would permit of a ready detection, and would better serve to illustrate the truth of the principle involved. For this purpose, trials were made with oil of cinnamon, wintergreen and peppermint; also horse manure and urine of cows. The results of this second series of tests are shown in table 2, on page 107.

In this set of data, the previous conclusion is abundantly confirmed, that the odor in the warm milk is more intense than in the cold, signifying that absorption takes place in a greater degree where the milk is warmer than the surrounding air. In 148 cases out of 171 or 86 per cent., the judges decided independently, that the odor peculiar to the different tests was more apparent in the warm than in the cold milk.

If this is true, the question may be asked why this percentage of correct judgment is not greater than here appears. In answer to this it should be borne in mind that this method of scoring where reliance has to be placed entirely on the sense of smell or taste is an extremely hazardous one. So many circumstances enter in from time to time, to dull the keenness of the senses, that even an expert fails to accurately judge such cases in every instance. In several cases where conflict in judgment was recorded, it had previously been noted before the scorer passed judgment that he had a bad cold or was temporarily unfit for this duty.

TABLE 2.—*Relative absorption of odors in warm and cold milk.* (Second series.)

KIND OF ODOR.	Time of exposure.	No. of tests made.	NO. OF TESTS WITH STRONGER ODOR IN		AVER. RANGE IN TEMPERATURE OF MILK, ° F.		Ave. temp. of air, ° F.
			Warm milk.	Cold milk.	Warm.	Cold.	
Oil of Cassia Cinnamon	½ hour.	20	12	7	83	52	70
	1 hour..	20	15	5	....	....	....
	1½ h'rs.	20	12	5	....	....	....
Oil of Wintergreen.	½ hour.	16	13	3	90	57	68
	1 hour..	16	14	2	....	....	....
	1½ h'rs.	16	16	....	....	....	....
Oil of Peppermint..	½ hour.	12	12	....	72	49	65
	1 hour..	12	11	1	....	....	....
	1½ h'rs.	12	12	....	....	....	....
Horse manure......	½ hour.	3	3	....	83	45	70
	1 hour..	3	2	....	....	....	....
	1½ h'rs	3	3	....	....	....	....
Urine of cow.......	½ hour.	8	7	....	82	44	69
	1 hour..	8	8	....	....	....	....
	1½ h'rs.	8	8	....	....	....	....

Then again, reference to the table indicates that the conflicting decisions were for the most part made in those tests, in which the exposure was, for the half hour or hour period, showing in some cases that sufficient time had not elapsed to impart a definite taint to the milk. In only a very few instances was no odor at all perceptible.

In the above experiments, the temperature ranges fluctuated materially from time to time, and it was thought that possibly the conflicting decisions might be correlated with those days in which the temperature range between maximum and minimum was the least. A study of the original temoerature records, which are not given in full here for lack of room, shows, however, that this relation could not be established. In fact, the fluctuations between maximum and minimum temperatures were often considerably greater on the days when the decisions of the two judges were not uniform than at other times.

This indicates that the personal factor enters very strongly into decisions made in this way, and that this must be taken into consideration in interpreting the record.

RELATIVE ABSORPTION OF DIFFERENT ODORS.

Regarding the relative intensity of odors absorbed, the essential oils seem to be taken up more actively by the milk than the other substances. Of these peppermint is the most readily absorbed. In exposures made for 10, 15 and 20 minutes, a slight though distinct trace of this odor could be detected in the warm milk. The odor arising from fresh horse manure did not seem to be absorbed in as marked degree as any of the oils.

The odor of fresh urine readily taints the milk, but stale urine does not seem to impart as marked an odor. As the volatile ammonia which is generally evolved from decomposing urine is not absorbed as readily in warm as cold liquids. it was thought that this property might change the general results; but there seems to be a peculiar odor arising from urine independent of the ammonia contained, that imparts to milk an undesirable taint that is readily recognized by the judges. It seems strange that definite opinions of practical men on this question of odor absorption should be at variance with the facts experimentally determined, but if one stops to consider and compare the universal belief of the housewife as to the relative power of warm or cold foods to absorb odors when placed in a refrigerator. he will see that the popular dairy belief does not coincide the experience of the kitchen. Warm foods are not placed in the refrigerator, for the reason, as the housewife avers, that they spoil sooner than would be the case if they were allowed to become thoroughly cooled. In her experience certain vegetables, butter, milk and like substances "take up" more readily the odors of the ice box, if they are placed in the refrigerator warm than if cool.

In the light of the above data, the common dairy expression that milk "gives off" odors when warm, and "takes them up" only when cooler than the surrounding air stands in need of modification. Undoubtedly, milk absorbs odors (pleasant and otherwise) when it is either warmer or cooler than the surrounding air, but this absorption is much more active in warm than in cold milk. The question as to the giving off of odors is not touched upon in this connection.

From the foregoing data, it is evident that leaving the milk in the stable for any considerable length of time is contrary to good dairy practice. Such a treatment renders possible not only the introduction of bacterial life from the germ laden air, but the direct absorption of stable odors that will seriously impair the value of the milk for direct consumption, or factory use. It may be said that if the milk is not allowed to remain longer than during the milking process, the danger is so small that it can be safely neglected, but such a practice is not to be advocated. If the stable is kept thoroughly cleaned and is well ventilated, perhaps an exposure for a few minutes might not produce serious results, but, if one is attempting to produce as perfect an article as it is within his power to create — and who is there that ought not to be included in this class — then such a method is fraught with danger even from the purely physical standpoint, let alone the biological phase of the question.

"STICKY" OR "SLIMY" BREAD AND ITS CAUSE.

H. L. RUSSELL.

During the past two seasons, the writer has noted an abnormal fermentation of bread that is the cause of considerable complaint. Our attention was first directed to it in July of last year when we received a loaf of wheat bread that had undergone a slimy decomposition. This bread had been prepared in the ordinary way, compressed yeast being used to develop the necessary fermentation.

When first baked the loaf showed no signs of an abnormal character; in fact, a part of the baking had been consumed before the change became apparent. In the course of three or four days after baking, the bread began to change in color slightly, assuming a light brown tint. It had a sweetish taste and a peculiar odor. When touched it appeared sticky, a condition that later became so marked that it would string out in long threads several feet in length.

During the month of July, two cases from different places came under my observation, and in the same month I received a letter from Dr. Frank W. Epley, President of the Wisconsin Medical Society, reporting an outbreak of the trouble in Dodge county of this state.

During this year, frequent complaints have also been received concerning a similar trouble. All of these cases appeared during the months of July, August and September. At least six or seven samples of sticky bread have been secured from different parties in Madison. Inquiry at the shops where yeast is sold elicited the fact that the trouble was a general one, much complaint having been made on the part of purchasers as to the quality of the yeast.

Last year samples of such bread were submitted to a bacteriological examination and numerous colonies of a well characterized organism were isolated, that upon further study proved to be the well known potato bacillus (*Bacillus mesentericus vulgatus*). This year all samples that were secured were likewise examined bacteriologically with the same result.

Infection experiments made by inoculating dough with a culture of this organism showed that it was able to withstand the baking temperature where bread was baked for an hour and a quarter. Such an abnormal change in bread has been previously reported. Uffelman* in 1890 gives a similar instance where *Bacillus liodermos* and *Bacillus mesentericus vulgatus* were found in rye bread that had undergone a similiar putrefaction. Kratschmer and Niemitowitz† also cite a case where graham bread underwent an analagous change.

The manner in which the bread becomes infected is a question of practical importance. It has been reported where different brands of flour were used; also where four kinds of yeast cakes and compressed yeast were employed. At first thought it might seem that the yeast was not at fault, but samples of bread made from yeast that had been used in the original baking developed the disease. The trouble also appeared in one household where white and graham bread was made in which the same yeast was used· This would indicate that the yeast was at fault and that it contained the potato bacillus as a common form of contamination.

This bacillus has very great powers of resistance toward dry heat as is shown by the following data taken from Vignal's‡ work:

When the bacilli are in a vegetating condition, an exposure to a heat of 150°F. for an hour is fatal. If heated in the presence of air to 195°F., a momentary exposure suffices to destroy them. If the organisms are in a spore stage, fifteen minutes exposure in a moist state at 249° F. is necessary to destroy vitality; if in a dry condition 300° F. for twenty minutes is required.

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* Centralblatt für Bakteriologie, Bd. 8, 481.

† Aus. d. Chem. Lab. d. k. k. öster. Militärsanitäts Comite, 1889.

‡ Vignal, Inaugural Thesis, Paris, 1889, p. 36.

From these observations it is evident that this germ possesses great powers of resistance, and therefore, would not be destroyed, if it existed in the dough, unless the heat used in baking was very high and continued for a considerable period of time. In order to determine whether the heat as ordinarily applied would be sufficient to destroy the germ in a spore-bearing condition in the dough, the following experiments were made:

Experiment 1. Graham gems were made in small "gem tins" and the temperature of the oven and inside of the gems recorded at different stages of the baking. It required thirty-five minutes to bake them and at the end of this time, the temperature in the oven outside was 356° F. while that inside of the gem was only 212° F. There was then a difference of 144° F., between the inside and outside, although the mass of dough was no more than a couple of tablespoonsful.

Experiment 2. The experiment was repeated with an ordinary baking of wheaten bread. In this case the inside and outside temperature was as follows:

Variation in temperature of bread and oven during baking.

	Inside of bread.	Oven.
	° F.	° F.
Bread placed in oven at 11:45 a. m		
12:00 m	122	220
12:15 p. m.	194	268
12:30 p. m.	203	284
12:45 p. m.	203	239
1:00 p. m.	206	239
1:15 p. m.	206	230

After baking for an hour and a half, the temperature at no time had been sufficiently high to destroy this organism, if it had been in a spore stage. These experiments on the insufficiency of the baking temperature to destroy the germ in a latent condition, in connection with the experiment already mentioned, where infected yeast was used show conclusively that these bacteria would not be destroyed under ordinary treatment.

Undoubtedly if the yeast is impure, as it appears to have been in these cases, such troubles will be more or less common, especially if the weather should be such as to favor bacterial growth.

The difficulties reported this year were all noted during the hot season, and under these conditions the spore forms of this organism that would not be killed in the baking process would germinate and grow rapidly in the bread after it was baked.

Until greater care is used by the yeast manufacturers in the preparation of their yeasts, such troubles are likely to occur during the hot summer weather. The only help that can be suggested is to hold the bread at a low temperature after it is baked, so that the spores that are present in the same will not germinate so rapidly. This combined with small bakings that are used up within two to three days will materially diminish the difficulty.

Just how such foreign organisms find their way into the yeast has not yet been studied. The trouble need not cause any special alarm from a sanitary standpoint for the organism causing the change is a saprophytic form that is widely spread. As soon as the fermentative change begins to be well marked, it is apparent enough to the taste so that bread affected with the same would be quickly rejected as food. Considerable losses, however, are reported and from the economic standpoint, the matter during this past year is by no means an insignificant one.

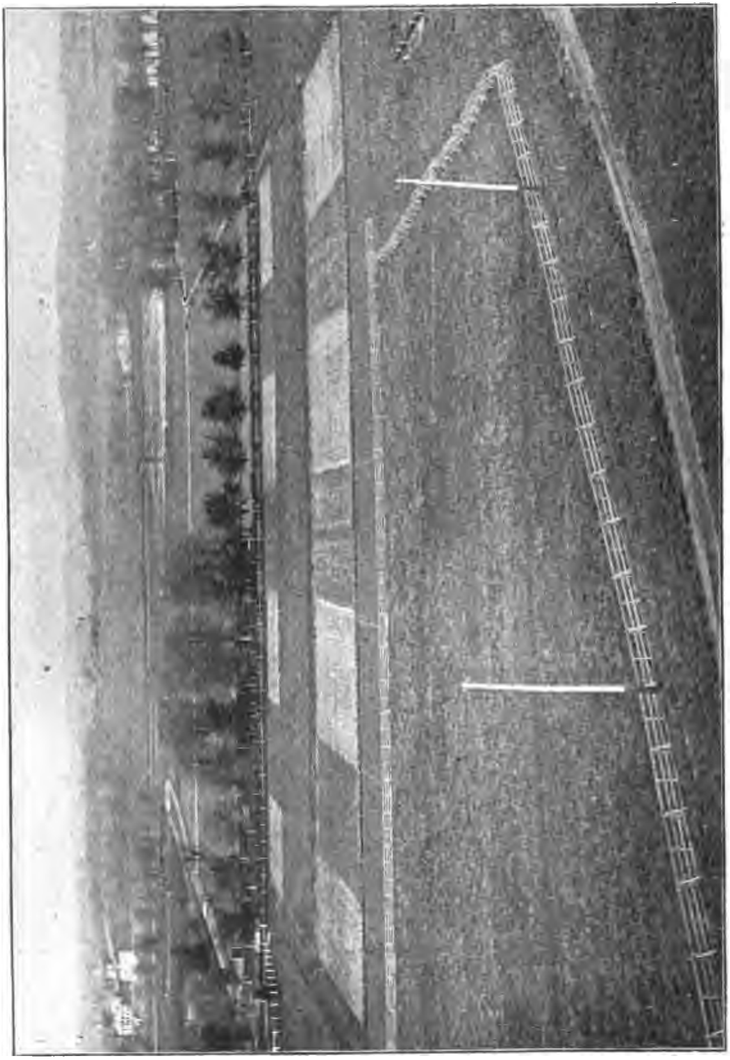

FIG. 16.—Showing the influence of early and late spring plowing on the moisture in the soil. The light colored areas were plowed last and are driest.

THE INFLUENCE OF EARLY SPRING TILLAGE ON SOIL MOISTURE AS COMPARED WITH LATER SPRING TILLAGE.

F. H. KING AND J. A. JEFFERY.

In the photo-engraving, Fig. 16, are shown two fields which were plowed at two different times in the spring, early and late, to note the influence of early tillage (a) on the soil moisture; (b) on the development of nitrates in the soil; and (c) on the yield of crops. We report here upon the first point only.

The three dark colored strips shown in the engraving of the two fields were plowed 6 inches deep and smoothed on April 12th; then disked on April 29th and again on May 7th. On May 12th to 14th the four light colored strips in each of the two fields were plowed 7 inches deep. The whole of the field in the back-ground was smoothed with a light harrow; but the one in the fore-ground, being clover sod, was first rolled and then disked three times lapping half and going first crosswise, then lengthwise and again crosswise over the whole piece. This piece was then smoothed, marked and planted to potatoes.

On the night of May 14 and the morning of the 15 it rained .61 inches and at 10 A. M. on the 16, about 28 hours after the close of the rain, the photograph reproduced in the engraving was taken and shows in a striking manner to the eye a difference in the moisture relations of the two fields plowed at different times in the spring. Between May 18 and the 22, 2.12 inches more rain fell and yet on May 24th the same marked contrast in moisture relations were visible to the eye which are shown in the engraving, the later plowed plots being the drier and lighter colored as shown.

On May 16, after the photograph was taken, samples of soil were also taken in one foot sections to a depth of 3 feet, each sample being a composite of five. The samples were taken along a line about 12 feet from the margin of adjoining plots and the members of each pair opposite each other. The results given in the table are from the north and south side of one of the early plowed plots and from the adjacent sides of two of the late plowed plots.

Table showing the difference in moisture of soil after early and late spring plowing.

Depth.	CLOVER SOD.		POTATO GROUND.	
	Plow'd Apr. 12,	Plow'd May 12.	Plow'd Apr. 12	Plow'd May 14
1st foot	24.98	22.55	24.18	21.51
2d foot	23.63	23.39	21.80	20.80
3d foot	22.50	21.30	17.80	18.36

It will be seen from this table that on the day the photograph was taken the early plowed ground contained much the largest amount of moisture, and yet during the time between the plowing and the taking of the samples ther had been a rainfall of 4.23 inches.

For every 100 pounds of soil of the early plowed ground there were in the

First foot of clover sod	2.43 lbs. mo water
Second foot of clover sod	.24 lbs. more water
Third foot of clover sod	1.20 lbs. more water
First foot of potato ground	2.67 lbs. more water
Second foot of potato ground	1.00 lbs. more water
Third foot of potato ground	.56 lbs. less water

That is to say in every 300 lbs. of the upper three feet of soil on the clover sod there had been a saving of .3.87 lbs. of water, while on the potato ground there had been a saving of 3.11 lbs. of water. These amounts of water saved when expressed in pounds per each square foot of surface in the field is about 3.49 on the clover sod and 2.45 lbs. on the potato ground, or a mean of .57 inches of rainfall.

IMPORTANCE OF THE RIGHT AMOUNT AND THE RIGHT DISTRIBUTION OF WATER IN CROP PRODUCTION.

F. H. KING.

The rainfall of the present season for the first time since 1888, when we began our studies of the relation of soil moisture to crop production, has been sufficient in quantity and so well distributed as to permit nearly maximum yields to be produced. In many parts of the state second crops of hay have been cut which are nearly or quite as heavy as good first crops usually are. It will be a matter of general interest therefore to know just what this rainfall has been and how it was distributed through the growing season.

RAINFALL AT MADISON DURING THE GROWING SEASON OF 1898.

In the table which follows, the rainfall from the beginning of April to the end of September is arranged so as to show its actual distribution and the amount which fell during each succeeding interval of ten days.

Table showing the rainfall for the growing season of 1898 and its distribution by 10-day periods.

Date.	Rain fall. Inches.	Rain fall per 10 days. Inches.	Date.	Rain fall. Inches.	Rain fall per 10 days. Inches.	Date.	Rain fall. Inches.	Rain fall per 10 days. Inches.	Date.	Rain fall. Inches.	Rain fall per 10 days. Inches.
Apr. 9	.20	......	May 18	1.45	......	June 25	2 04	......	August 16	.07	1.20
10	.01	.21	20	.49	2.55	29	.11	2.87	23	.02	......
13	.37	......	21	.17	......	July 1	.15	......	24	.18	......
17	.05	......	22	.01	.....	2	.02	.....	26	.24	.44
18	.49	......	27	.45	......	3	.12	.29	Sept. 4	.21	.....
19	.70	1.61	28	.10	......	19	2.55	2.55	5	.24	......
21	.18	......	29	.02	.75	20	.05	......	6	.04	.49
22	.25	......	June 1	.03	......	29	.05	.10	13	.77	......
28	.06	......	9	.08	.11	30	.01	......	14	.18	......
30	.07	.56	10	.66	......	31	.02	......	15	.07	1.02
May 1	.02	......	12	.80	......	August 1	.01	......	23	.04	.04
2	1.31	......	14	.02	1 48	2	.50	......	30	.08	......
9	.02	......	20	.08	......	3	.40	......			
10	.06	1.41	21	02	......	6	.01	.95			
14	.38	......	23	.50	......	10	.83	......			
15	.23	......	24	.12	......	15	.80	......			

It will be seen from this table that there has been but one interval of 15 days' duration when no rain fell and .4 inches is the smallest rainfall during any 20 consecutive days, this period being between June 29 and July 19th. The largest rainfall in any 20 consecutive days was 4.11 inches and 2.94 inches was the greatest fall in any 10 consecutive days, so that little water was lost by percolation.

THE YIELD OF HAY.

Under these conditions the first crop of clover hay was cut on plots 1 and 3, Fig. 22, p. 216 of Report for 1897 on June 14, the yield being 5,549 lbs. on the former and 4,780 lbs. of hay, containing 15 per cent. of moisture, on the latter per acre.

Plot 5 was plowed the previous fall and on April 15th sowed to oats and seeded to clover. On July 6 this was cut for hay yielding 6,766 lbs. per acre containing 15 per cent. of water. Plot 8, in 1897, had been seeded to alfalfa without a nurse crop but the weeds were so abundant that they were turned under and the present season the ground was disked on April 17, on April 30 and again on May 7 when it was smoothed and sowed to oats and seeded to alfalfa. On July 6 this was also cut, yielding 4,328 lbs. of hay per acre containing 15 per cent. of moisture.

On July 9, following the cutting of the two pieces of oat hay, both pieces were irrigated to force the alfalfa and clover. They were again watered on Aug. 13 and Sept. 3, and on Sept. 15 both pieces were cut for hay, both the alfalfa and the clover being in full bloom. The clover yielded 4,378 lbs. of hay per acre and the alfalfa 2,729 lbs. per acre, containing 15 per cent. of moisture. The alfalfa at this writing, Oct. 1, has already attained a height of 11 inches and the clover 6 inches after the second cutting from the seed.

Last year plot 1 was seeded to clover with barley, and after harvesting 46 bushels of barley per acre the ground was irrigated on Aug. 20 and on Sept. 8, with the result that on Sept. 22 we cut 1.36 tons of hay per acre containing 15 per cent. of water. It appears clear therefore that with plenty of moisture in the soil it is possible to seed ground to clover or alfalfa with oats or barley and cut the same season from 1.5 tons to 2 tons of hay per acre from the same ground, as a second crop. Our yields this year were as follows:

	Ground seeded to alfalfa.	*Ground seeded to clover.*
First crop of oat hay	2.164 tons per acre.	3.355 tons per acre.
Second crop of clover hay	1.365 " "	2.189 " "
Total first season	3.529 " "	5.544 " "

After cutting the clover on plots 1 and 3, June 14, the ground was irrigated on June 21 and July 18. On August 5 the second crop of clover was in full bloom and cut yielding from plot 1, 2,593 lbs. of hay containing 15 per cent. of moisture, and from plot 3, 3,203 lbs. per acre. On Sept. 2 these plots were again watered and the third crop of clover, in nearly full bloom, was cut Oct. 5, yielding 1,899 lbs. per acre on plot 1, and 1,654 lbs. per acre on plot 3 of hay containing 15 per cent. of moisture. The total yield for the season, therefore, on these two plots was as follows:

	CLOVER HAY CONTAINING 15 PER CENT. WATER.	
	On Plot 1. Tons per acre.	On Plot 3. Tons per acre.
First crop cut June 14	2.775	2.390
Second crop cut Aug. 5	1.297	1.602
Third crop cut Oct. 5	.950	.827
Total yield	5.022	4.819

In these cases the first crop was produced by the natural rainfall. A second crop of nearly a ton per acre could have been secured had no water been applied, but the third crop was made possible only by irrigation.

The yields of hay for the first and second crops during the past three years have averaged

Eor 1896, 4.044 tons per acre, containing 15 per cent. water.
For 1897, 4.434 tons per acre, containing 15 per cent. water.
For 1898, 4.031 tons per acre, containing 15 per cent. water.

THE YIELD OF CORN.

The present season corn was again grown upon plot 9, thus making the fifth crop in succession on the same ground without fertilizers, and the yields per acre are given in the table below:

YEAR	KIND OF CORN.	NOT IRRIGATED.		IRRIGATED.		DIFFERENCE IN WATER USED.	DIFFERENCE IN YIELD.
		Inches of water.	Pounds of dry matter	Inches of water.	Pounds of dry matter	Inches.	Pounds of dry matter
1894..	Flint....	8.15	7,916	16.76	11,080	8.61	3,164
	Dent		7,426		9,625		2,199
1895..	Flint....	4.48	2,458	31.08	10,048	26.60	7,590
	Dent		3,144		11,125		7,981
1896..	Flint....	15.02	8,129	27.07	10,320	12.03	2,191
	Dent		8,450		10,280		1,830
1897..	Flint....	10.66	6,766	16.36	8,571	5.70	1,805
	Dent		6,853		8,438		1,585
1898..	Flint....	11.02	7,558	16.72	6,882	5.7	—776
	Dent		7,581		7,330		—251

It will be seen from the table that the yield on the irrigated ground this year has been less than that on the ground not irrigated, and although the ground received practically the same amount of water as last year the yield was less with both varieties of corn and to a notable extent. With the corn on the not irrigated ground, however, the yield per acre was nearly as large as the first crop on the ground.

These results appear to emphasize those of last year in suggesting that the fertility of the irrigated ground is being seriously impaired. As this is one of the points it is desired to demonstrate the experiment will be pushed still further until there can be no question of the cause of the results.

Corn was also grown upon plot 2, Pride of the North dent being planted after potatoes without manure. The corn was planted in rows both ways 30 inches apart and one sub-plot was thinned to two stalks in a hill, while two sub-plots on either side were thinned to four stalks in a hill. When the corn was irrigated on Aug. 1, twice the amount of water was given to the thick seeding.

The yield of dry matter per acre for the two stalks in a hill and the smaller amount of water was 7,908 lbs. per acre and for the 4 stalks in a hill and the larger amount of water it was 10,015 lbs. per acre. As the whole of this plot was irrigatated there is no check upon the yields per acre under natural rainfall conditions.

Plot 6 was planted to a variety of white dent in hills 30 inches each way, and in this case also a part of the rows were thinned to 2 stalks in a hill while the balance were thinned to 4 stalks, and when irrigated on Aug. 2 and Aug. 20, were given twice the amount of water given to the two stalks in a hill. There was one sub-plot in this piece of corn thinned to 2 stalks in a hill which was not irrigated, and the yields of dry matter per acre were as follows:

Irrigated:	
Total dry matter per acre, 4 stalks in a hill	11,753 lbs.
2 stalks in a hill	9,594 lbs.
Not irrigated:	
Total dry matter per acre, 2 stalks in a hill	10,940 lbs.

The results show that the corn not irrigated gave a larger yield than that which was irrigated. We feel quite sure, however, that this difference is due to some error in weighing the loads, and this conviction rests upon the fact that the yield of ear corn from the not irrigated ground was less than that on the irrigated ground, and the fact that the not irrigated corn before cutting appeared to the eye lighter than that which had been watered. It is certain, however, that the watering of corn this year could make but little increase of yield per acre.

THE YIELD OF POTATOES.

The work this year with potatoes was carried out on plots 4 and 6, the two areas covering together a little more than two acres. Plot 4 was clover sod plowed and treated as described in the section relating to early spring tillage on page 115, and plot 7 was, in 1897, clover sod planted to corn. This spring it was given a dressing of well rotted farmyard manure at the rate of 20 wagon loads, of 64 cubic feet, per acre, and plowed and smoothed on April 16. Later it was disked on April 30, May 7 and 17, and finally fitted and planted on May 24 to Rural New Yorker potatoes in hills 30 inches apart each way. Plot 4 was planted with the same variety of potatoes on May 13 and 14 and in the same manner. Both fields were harrowed and cultivated both ways until near the middle of July, when they were hilled preparatory to irrigation.

We were unfortunate this season in being obliged to use seed low in vitality, the defect being due to the fact that the potatoes were wintered in a cellar which was too warm. Although the cellar was absolutely dark the tubers began to grow in February and early in March had sprouts on them two inches long. When the seed was planted not all of it grew and many of the plants which did so were dwarfed from the start and remained small throughout the season. Prof. Goff planted the same seed which had wintered in a cooler place and secured 385 bu. per acre on similar ground.

Each field was divided into alternating sub-plots of 7 irrigated rows and 7 rows not irrigated, while one row between adjacent sub-plots was irrigated on one side only. The lower ends of both plots were so flat that after one of the heaviest rains water covered a large part of the ground, and on plot 7 this portion of the ground was so wet throughout the season that the water during irrigation was not allowed to run the full length of the rows.

Plot 7 was watered but once on, Aug. 24, and the south end of Plot 4 was irrigated first on Aug. 24 and the whole plot again Sept. 3. The yields from the two plots are given in the table which follows:

	IRRIGATED. Bu. per acre.		HALF IRRIGATED. Bu. per acre.		NOT IRRIGATED. Bu. per acre.	
	Large tubers.	Total yield.	Large tubers.	Total yield.	Large tubers.	Total yield.
Plot 4	159.27	183.7	160.25	182.1	151.48	173.4
Plot 7 North	187.9	204.9	184 5	200.9	161 1	175.9
Plot 7 South	189.2	208.1	174.5	193.6	178.8	199.9

It will be seen from these figures that the irrigation in each of three cases increased the yield to a measurable extent, the mean difference being 8.65 per cent. and these results when combined with the very large increase in yield which irrigation produced in both 1896 and 1897, as indicated in the reports for these years, appears to establish the fact that with potatoes, as with hay, the rainfall of Wisconsin is seldom so large in quantity or so well distributed but that good and timely irrigation will measurably increase the yield.

A NEW METHOD FOR THE MECHANICAL ANALYSIS OF SOILS.

F. H. KING.

The methods of mechanical analysis of soils which have heretofore been in general use have aimed primarily to secure by one means or another a separation of the soil grains of the sample under examination into a certain number of groups where the diameters in each "separate" shall all have dimensions falling within an upper and lower limit. In addition to this sorting of the soil grains into groups on the basis of diameters an effort has also usually been made to determine the percentage amount of each group of sizes which is found in the particular sort of soil.

These methods of determining the extent of physical subdivision of soils are all of them not only very laborious and time-consuming processes, but they give results in such a form that it has not yet been possible to use them in any definite way to predict either the water capacity of the soil, the rate at which water and air may move through the soil or the aggregate amount of surface which a unit volume or unit weight of it may present to the solvent and corroding action of soil-water and soil-air or to the roots of plants.

We are greatly in need of a method of soil examination which shall give definite data regarding the *effective surface* of a unit volume of soil both for the holding of soil moisture and for the solution of plant food; one which will give the *effective diameter* of the soil grains or *grouping of soil grains* which determines the water-holding power or saturation capacity of a soil, and which determines the rate of percolation and of air movement through it. We need a method of soil investigation which will be able to show whether or not the grouping of soil grains in a virgin soil is fundamentally different from what it is in the same soil after it has been long under cultivation.

The methods of mechanical analysis of soils which have been in general use cannot give a very close measure of the aggregate amount of surface possessed by a unit volume of a given soil as the following problem will show:

Let a soil be assumed composed of grains of but two sizes (a) .009 and (b) .00015 m. m. Let these be mixed in the proportion of

A. 90 per cent. of (a) with 10 per cent. of (b)
B. 10 per cent. of (a) with 90 per cent. of (b)
C. 50 per cent. of (a) with 50 per cent. of (b)

Under these conditions the surface of one grain of such mixtures of soils whose grains have a specific gravity of 2.65 is

For A.

	Surface.	
90 per cent. of grains (a) .009 m. m. diam	2,264	sq. c. m.
10 " " " (b) .00015 m. m. "	15,094	"
Aggregate surface	17,358	"

For B.

10 per cent. of grains (a) .009 m. m. diam.	251 6	"
90 " " " (b) .00015 m. m. "	135,848.9	"
Aggregate surface	136,100.5	"

For C.

50 per cent. of grains (a) .009 m. m. diam.	1,258.0	"
50 " " " (b) .00015 m. m. "	75,481.7	"
Aggregate surface	76,739.7	"

If we compute the number of grains in one gram of each of these three mixtures they will be as given below:

	A	B	C
(a)	889,753,061	98.861.363	494,306,818
(b)	21.354,187,192,118	192.188.053,097,345	106,770,833,333,333
Total...	21,355,076,945,179	192,188,151,958,708	106,771,327,640,151

It has been the custom of different investigators to get the diameter of soil grains either by direct measurement with a micrometer or by counting and weighing a certain number of grains and then computing the diameter of the mean grain from the specific gravity, number and weight. But in order to get results which are even approximately accurate a large number of measurements in three dimensions of the grains must be made and a large number of the grains must be counted and weighed. We have found for example that with a sorted sand having grains approximately .45 m. m. in diameter it was necessary to count more than 1,000 grains in order to have duplicate lots agree, by weight, to the third decimal place; so that the amount of labor involved in making these determinations after the separations are made is very great.

Nor is this all, for when values have been procured by the two methods they cannot give results which agree. This will be seen from the following considerations:

If we take the problem above and divide the sum of the diameters by the total number of grains or divide the total weight of grains by the number of grains and compute the diameter of the grain of mean weight it will be found to be

	Diam. from weight.	*Diam. from measurement.*
for A	.0003232 m. m.	.0001504 m. m.
for B	.0001554 m. m.	.0001500045 m. m.
for C	.0001890 m. m.	.00015000111 m. m.

Then if the surfaces in one gram of the soil is computed from these mean diameters they will differ from the true surfaces by the amounts given in the following table:

A.	B.	C.
	Actual surface per gram of soil.	
17,358 sq. cm.	136,101 sq. cm.	76,740 sq. cm.
	Surface computed from the grain of mean diameter.	
150,570 sq. cm.	150,939 sq. cm.	150,902 sq. cm.
	Surface computed from grain of mean weight.	
70,063 sq. cm.	145,734 sq. cm.	119,804 sq. cm.

These results are plainly too widely divergent to make them of much value when we wish to know what is the actual surface a given soil may present to the action of solvents.

It has been customary with some writers in computing the amount of surface a soil contains to take the arithmetical mean diameter of the largest and smallest grains in a particular grade or "separate" as the diameter of the mean grain and if this is done in the above problem the results will stand as given below:

Computed from the mean of the two extreme diameters.	*Computed from the true diameters in true proportions.*		
	A	B	C
4,949 sq. c.m.	17,358 sq. c.m.	136,101 sq. c.m.	76,740 sq. c.m.

These results show that even when a soil has been separated into a large number of sizes that it is not possible, even working with the "separates," to arrive at a very exact knowledge of the real surface which the soil may possess per unit volume or weight.

It was after considering some of these difficulties that in 1894 we attempted to devise a means of utilizing the laws of flow of water through capillary tubes in gaining a knowledge of the pore space in soils and the extent of its subdivision. After we had worked with the flow of water through simple sands and had encountered great difficulties in duplicating results a study of the flow of air through the same media was resorted to. It was found so much easier, simpler and expeditious to use air, and results could be duplicated so much more closely that we were encouraged to apply to Prof. Charles S. Slichter for his opinion as to the possibility of placing the method on a quantitative basis.

After considering the subject it appeared to him that in view of the accepted laws of flow of air and of water through capillary tubes and the extensive experiments which had been made to determine the viscosity of both air and water it ought to be possible to compute the effective diameter of the soil grains from a knowledge of the observed pore space, and the rate at which air would flow through the specimens under known conditions.

After his preliminary formula was found to give results with our improvised apparatus which were closer than had at first been expected, the apparatus represented and described under Fig. 19 was constructed and tested on quite a wide range of materials. Since it was not admissible to test the accuracy of the method by means of diameters computed from direct measurement of diameters or by counting and weighing, the method of computing the theoretical flow of water through the same sample and then comparing this with the observed flow was resorted to with results given in the table below and we have also given in the same table the theoretical flow computed from the diameter of the sand grains as found by counting a large number in duplicate lots.

Table showing observed and computed flow of water through simple sands of different diameters under a pressure of 1 cm. of water.

GRADE OF SAND.	DIAMETER OF GRAINS.		FLOW OF WATER THROUGH THE SAMPLE.		
	By counting and weighing.	By aspiration of air.	Observed.	Computed from aspiration diameter.	Computed from count and weight diameter.
	mm.		gms.	gms.	gms.
8	2.755	2.54	2,296	2,277	2,680
7	1.993	1.808	1,080	1,132	1,372
6	1.588	1.451	756	757	909.1
5½	1.345	1.217	542	522	638.6
5	1.157	1.095	504.6	453.2	499.6
4	.976	.9149	329.2	297.5	326.6
3	.8017	.7988	210.0	193	194.0
2	.6653	.7146	133.6	122	106.2
1	.5824	.6006	94.8	80.6	75.7
0	.4891	.5169	72.3	66.8	59.8

When it is observed that the flow of air through the sample of sand was not the identical sample through which the flow of water was measured and that it was in a different piece of apparatus, and further, that the flow of fluids through soils varies, theoretically, as the squares of the diameters, it will be conceded that, while there is not as close an agreement between the observed and the computed results as could be wished, the agreements are so close as to show that for such materials there is much more than a chance agreement. It will be seen further that in general there is a closer agreement between the observed flows and those computed from the aspirator diameters than with those computed from the count and weight diameters.

In doing this class of work with the aspirator it is supposed to give not the diameter of the mean soil grain which constitutes the sample but the diameter of an ideal soil grain which if put in the place of the actual ones would permit an amount of flow equal to that which is observed.

APPARATUS USED WITH COMPOSITE SOILS.

When the apparatus is used on composite soils it gives result like those stated below where, through the kindness of Prof. Milton Whitney, we have been able to use a set of his samples which he has analyzed mechanically.

Mechanical analysis of subsoils.

No.	Maryland.	By Whitney's Method. Gravel 2-1 m. m.	Coarse sand 1-.5 m. m.	Medium sand .5-.25 m. m.	Fine sand .25-.1 m m.	Very fine sand .1-.05 m. m.	Silt .05-.01 m. m.	Fine silt. .01-.005 m. m.	Clay .005-.0001 m. m.
		Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr ct.	Pr. ct.	Pr. ct.	Pr. ct.
471	Early truck soil ...	0.25	5.42	41.45	26.73	12.46	7.22	2.21	4.07
563	Early truck soil ...	0.39	7.04	37.51	21.45	13.45	10.72	3,72	5.41
141	Average wheat land	0.00	0.23	1.71	6 08	30.82	20.92	11.21	23.78
1045		0.19	1.80	3 12	6.96	8.76	34.92	12.14	28.82
173	Finest wheat and grass land........	0.54	0.32	0.72	0.62	4.03	36.02	14.99	41.24
934	Finest wheat and grass land	0.00	0.12	0.30	0.89	11.02	30.41	5.86	44.43

By King's method.

No.		Observed pore space.	Time required for the flow of 5,000 c. c. of air.	Effective diameter of soil grain.
		Per cent.	Seconds.	m. m.
471	Early truck soil........................	32.49	23,590	.1119
563	Early truck soil........................	34.45	41,960	.07555
141	Average wheat land	42.79	1,056,000	.01011
1045		48.00	993,000	.008612
173	Finest wheat and grass land.........	52.94	2,112,500	.004956
934	" " " "	45 93	1,477,300	.007657

These results appear to be in substantial agreement with those of Whitney unless it is in the case of Nos. 173 and 934. At any rate the results show that the soils are very widely different both in the amount of pore space which they contain and in the time which is required for 5 liters of air to pass through like columns of soil.

It is not, of course, intended to convey the impression that results obtained by the method here described will take the place of such as may be secured by that of Hilgard or the Osbern or by any of the European methods, but rather that it may enable us to approach the physical properties of soils by another and perhaps more direct method so far as movements of soil moisture and soil-air are concerned.

THE PORE SPACE OF SANDS AND SOILS.

The amount of unoccupied space in a dry soil differs quite widely with the character of the soils. This is brought out clearly in the table just given, where it is seen that the finest grained soils have the largest pore space, and yet if reference is again made to the table it will be seen that while the pore space in the sandy soil, No. 471, is only a little more than half as much as it is in No. 173, the air under like conditions travels through it 89 times as fast. So in like manner will water percolate through the coarse sandy soils very much faster than through the fine ones, and at the same time they will retain or hold backmuch less water.

Why this is so will be readily understood from an inspection of Fig. 17, which shows two arrangements of spheres in such a way as to give the largest possible pore space, 46.64 per cent., and the smallest possible pore space or 25.95 per cent. when the spheres are in contact. It will be seen that with both arrangements the largest spheres give but 16 large pores through which the water and air may flow freely; while where the spheres are one-half the diameter there are four times as many pores, and where the diameters are one-third as large there are nine times as many pores.

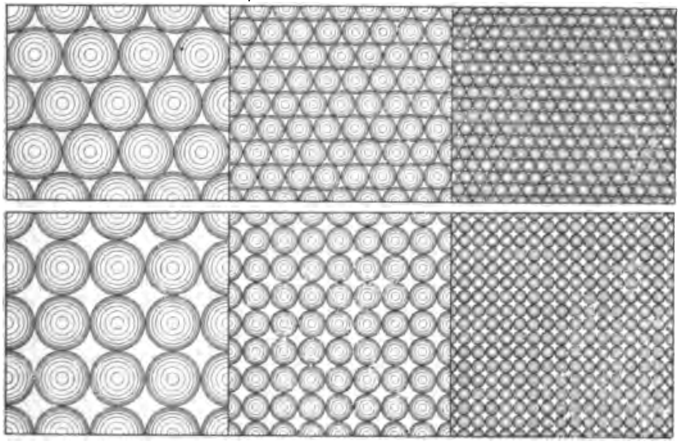

FIG. 17.—Showing the effect of the arrangement of soil-grains on the per cent. of pore space and why water and air flow through coarse-grained soils more rapidly than through fine-grained soils.

The pore space in each of these two series is just the same for the coarse and fine grains, but when air or water passes through the coarsest spheres it will be divided into but 16 streams, but in going through the second size it must be divided into 64 streams, and when through the finest grains then into 256 streams.

But to divide the water into 256 streams as compared with 16 streams causes the water to slip or slide along a much greater surface and hence the friction must be much greater in proportion to the amount of water which is passing, and this must make its movement much slower.

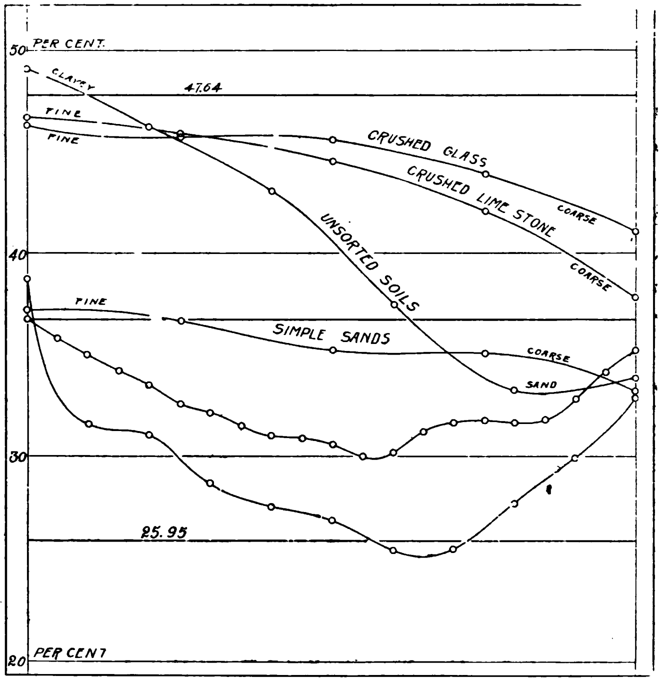

FIG. 18.—Shows the observed pore space of different kinds of soils and sands and their relation to the theoretical pore space of spheres of a simple diameter.

In Fig. 18 the pore space of several kinds of grains has been plotted. There is given first, a series of crushed glass; second a series of crushed limestone; third a series of soils varying from the finest to the coarsest; fourth a series of sorted sands with well rounded grains; fifth, in the next to the lowest curve in the figure, a fine sand having grains .1521 m. m. diameter and a coarse sand having grains .6112 m. m. in diameter are mixed in proportions increasing from left to right by regular steps of 5 per cent. beginning with the clear finest sand and ending on the right with the clear coarsest sand; sixth, the lowest, is like the last except that the finest sand used is not simple but contains all of the grains which are smaller than .1521 m. m. which the plastering sand contained as well as the size .1521 m. m.

It will be seen that with all of the samples the pore space is largest where the grains are smallest; that with the coarse grains the pore space is largest with the angular fragments and smallest with the sample sands; that the smallest pore space of all is found with the mixed sand and that this is smaller than the closest possible packing with spheres, which is 25.95 per cent. as shown in the figure; and finally that the largest pore space is given by the finest soil and that this is larger than the largest pore space given by the packing of spheres.

DESCRIPTION OF THE APPARATUS.

The apparatus for determining the effective size of soil grains consists of a water receptacle A, A, Fig. 20; an aspirator bell B. B; an air tube 1, 1, 1, leading from the bell to the air chamber D, D; a soil tube C, C, C, provided with a tight cap 4 at one end and a cap with wire gauze at 3.

The air meter is a clock gear shown in the photo-engraving Fig. 19; and the bell is calebrated to read seconds of dial in c/c. The pressure gauge connects at 2, 2, and is represented in the photo-engraving at the left consisting of a pressure tube rising 1 in 10 and connected with a large water receptacle used to avoid reading the gauge at both ends. Pressures can be read to tenths of a m. m. The pressure is developed by a weight shown in the photo-engraving. The soil tube C is given a capacity of 100,200 or 300 c. c. according as the soil used is fine or coarse, the area of cross-section being 11.3903 sq. c. m. in our case. Two bells are also used, one in which 1,000 c. c. and the other 3,000 c. c. may be measured, to be used with the fine and coarse soils.

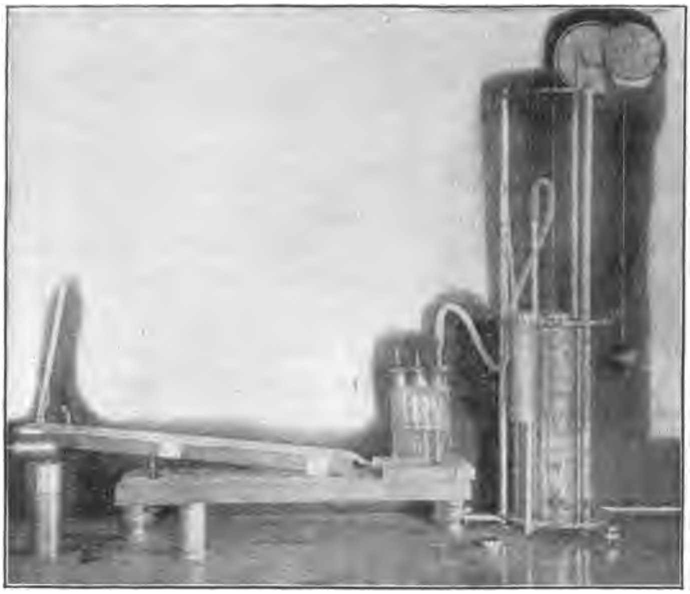

FIG. 19.—Apparatus for determining the effective size of soil-grains.

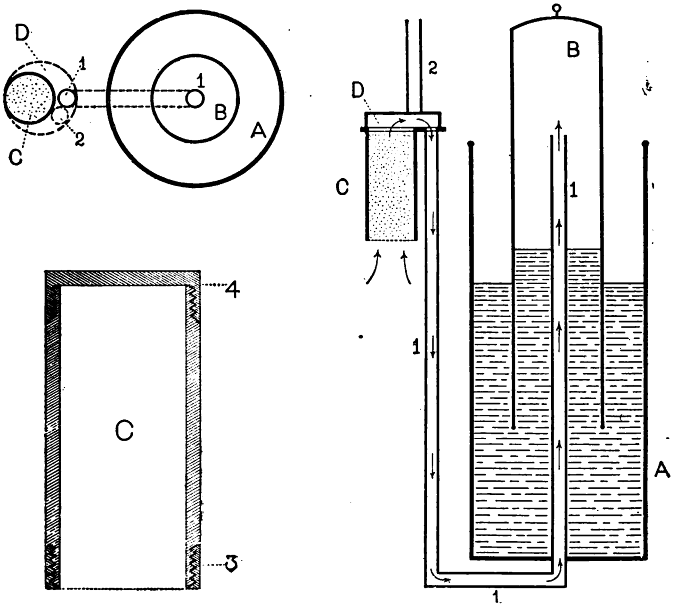

FIG. 20.—Detail of apparatus for determining the effective diameter of soil-grains. For description see page 131.

METHOD OF USING THE APPARATUS.

To fill the soil tube C the cap 4 is screwed down close and the cap 3 removed. The sample is then introduced in small lots at a time, 3 to 5 c. c., and gently tamped with a flat-faced pestle until level full, then it is held rigidly between the thumb and fingers and resting on the table and jarred by repeated light blows from a light stick turning the tube around as the jarring progresses. This is repeated as long as any settling can be produced and more soil is added and finally "struck off" and made even full with a piece of plate glass.

The object is to secure the closest possible packing. If violent jarring is resorted to or if the tube is not pressed firmly on the table while jarring the soil will be loosened up.

Soils may be sorted by means of screens and the effective size of the "separates" determined or the whole soil may be used as desired.

Where the aim is to get a measure of the finest grains the air-dry sample is rubbed down in a mortar with a rubber tipped pestle to remove lumps. If it is desired to investigate the soil as to its normal crumb-structure then the destruction of these would be avoided.

FORMULA FOR DETERMINING THE EFFECTIVE DIAMETER.

Prof. Slichter's formula for determining the effective diameter of the grain is as follows:

$$d^2 = k\frac{h}{spt} \qquad [8.9434 - 10] \text{ where}$$

d = diameter of grain in c. m.
h = length of sand column in c. m.
s = area of cross-section of sand column in sq. c. m.
p = pressure in c. m. of water at 20° C.
t = time in sec. for 5,000 c. c. of air to flow through at a temperature of 20° C.

[8.9434 — 10] is a logarithm of a constant
k is a constant taken from the following table:

Per cent. of pore space.	Log. k.	d.	Per cent. of pore space.	Log. k.	d.
26	1.9258	563	37	1.4173	377
27	1.8695	500	38	1.3816	371
28	1.8195	490	39	1.3445	367
29	1.7701	502	40	1.3078	353
30	1.7199	467	41	1.2725	351
31	1.6732	455	42	1.2374	345
32	1.6277	430	43	1.2024	339
33	1.5847	438	44	1.1690	320
34	1.5409	410	45	1.1370	312
35	1.4999	407	46	1.1058	329
36	1.4592	409	47	1.0729	....

A LABORATORY STUDY OF THE EFFECTIVENESS OF SOIL MULCHES.

F. H. KING AND J. A. JEFFERY.

In the experiments here recorded an effort has been made to obtain results under conditions which could be more rigidly controlled than is readily practicable in the open field.

Two series of experiments have been carried out. In the first three types of soil were used, in a form of apparatus represented in Fig. 21, which consisted of three sets of cylinders carrying the three types of soil placed side by side in a case as shown where a current of air could be maintained across the surfaces and its velocity measured.

Each cylinder used was of galvanized iron painted on the inside with an acid and water proof paint and provided with a water reservoir represented at E, Fig. 21, having a supply pipe D, which when not in use, was covered with a cap; and a tube at C to permit the escape of air when introducing water and to equalize the pressure. The water reservoir connects with the soil cylinder by a series of notches cut in the lower edge of the cylinder.

The height of each cylinder is 22 inches with an area of cross-section of one-tenth of a square foot, while the height of the soil column above the highest level of water in the reservoir was 19 inches.

In filling the apparatus two pounds of coarse plastering sand was placed in the bottom of each cylinder to provide a rapid and equal distribution of water under the whole soil column. On this sand the soil was placed, adding 325 c. c. at a time, and firming each lot with a flat faced iron pestle having a cross-section nearly equal to that of the cylinder itself. The pestle weighing 4.1 lbs., was raised and allowed to fall 12 times on each quantity of soil added. and when the cylinders were full their weights agreed among themselves to within from .25 to .5 of a pound.

The three soils used were (1) a black marsh soil of a very fine close texture and devoid of peat, which had been under cultivation but two years; (2) a sandy loam cultivated many years; and (3) a medium virgin clay loam from a second growth black oak grove. All the soil was thoroughly mixed and screened through a gardener's sieve and all cylinders of a set were filled at the same time by adding the stated lots of soil in rotation.

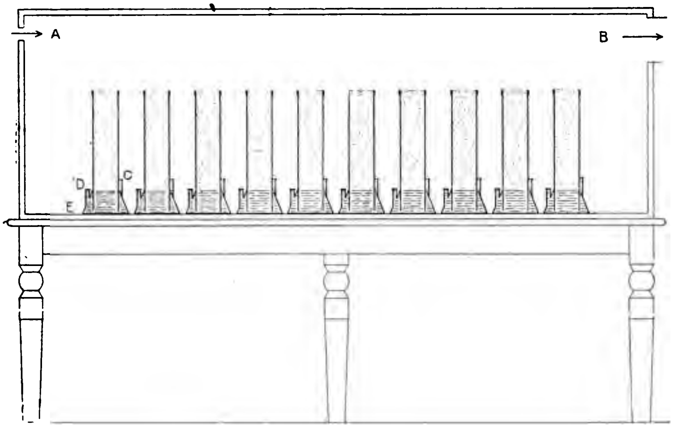

FIG. 21.—Showing apparatus for demonstrating the effectiveness of mulches. E is a water reservoir; D, supply pipe with close cover; C, tube for escape of air with pin hole opening; A, intake for air; B, exit for air to ventilating flue.

When the soil was added to the cylinders there was 53.91 per cent. of water in the black marsh soil, 23.91 per cent. in the virgin soil and 16.01 per cent. in the sandy loam; and the average weight of soil in each set of cylinders was 15.4 lbs., 15.81 lbs., and 18.0 lbs. respectively.

The object of the experiment was to determine the relative effectiveness of mulches 1 inch deep, 2 inches deep, 3 inches deep, and 4 inches deep as compared with no mulch at all, and each experiment was conducted in duplicate, there being 10 cylinders in each set arranged as shown in the figure where the two end cylinders had the suface of the soil firm and flush with the top. The mulches in each case were produced by removing the soil to the desired depth and working this into the crumbled condition, when so much was at once returned as was required to fill the cylinder level full. The second cylider from the ends in each case was mulched 1 inch deep, the third 2 inches, the fourth 3 inches, and the fifth 4 inches deep.

After the cylinders were in place with covers on, to prevent evaporation, the reservoirs were filled with water and more water added three different times, twice on the first day and once on the next, when the covers were removed and the preliminary period started. At this time the moisture had been increased in the black marsh soil to 56.37 per cent., in the virgin soil to 35.57 per cent., and in the sandy loam to 19.71 per cent.

It will be seen that we start here with three nearly saturated soils in which the permanent ground water is only 19 to 22 inches below the surface from which evaporation is to take place. Such conditions as these it would appear should better facilitate the rise of water into the mulches and its escape through their surface into the air by evaporation than would be the case where standing water were at a greater distance from the top of the ground. If this supposition is true then the effectiveness of the mulches as shown by the differences in the rates of evaporation should be nearer a minimum than a maximum value. On the other hand, since no water has been added to the surfaces of these soils to deteriorate their capacity as mulches, the conditions may be expected in this regard to give them a value nearer their maximum than their minimum. It is true, of course, that were water added to the surface of the unmulched cylinders the rate of loss from these would also be increased and this would tend to show the mulches more effective than would be the case were the loss from the unmulched surfaces slower.

The total amount of water added to each set of cylinders during the first preliminary period of 63 days was as follows:

	No mulch. Per 100 days.	Mulch 1 in. deep. Per 100 days.	Mulch 2 in. deep. Per 100 days.	Mulch 3 in. deep. Per 100 days.	Mulch 4 in. deep. Per 100 days.
Black Marsh Soil:					
Tons per acre	746.9	467.1	352.6	321.0	244.5
Inches of water	6.597	4.125	3.114	2.834	2.160
Per cent. saved by mulches	....	37.47	52.79	57.02	67.26
Sandy Loam:					
Tons per acre	934.2	523.7	402.1	347.6	288.3
Inches of water	8.692	4.625	3.550	3.070	2.546
Per cent. saved by mulches	....	46.79	59.15	64.68	70.71
Virgin Clay Loam:					
Tons per acre	1,602	1,487	1,482	1,415	1,277
Inches of water	14.15	13.13	13.08	12.49	11.28
Per cent. saved by mulches	....	7.21	7.51	11.67	20.29

During the second period of 80 days the amounts of water added were as follows:

	No mulch. Per 100 days.	Mulch 1 in. deep. Per 100 days.	Mulch 2 in. deep. Per 100 days.	Mulch 3 in. deep. Per 100 days.	Mulch 4 in. deep. Per 100 days.
Black Marsh Soil:					
Tons per acre	528	278 9	200 3	169 5	144.6
Inches of water	4.664	2.462	1.769	1.497	1.277
Per cent. saved by mulches	....	47.18	66.06	67.89	72.61
Sandy Loam:					
Tons per acre	482.5	293.9	225.2	172.5	151.9
Inches of water	4.261	2.595	1.989	1.523	1.341
Per cent. saved by mulches	....	39.06	53.32	64.25	68.52
Virgin Clay Loam:					
Tons per acre	1,323	1,002	625.9	619.6	484.0
Inches of water	11.68	8.847	5.528	5.471	4.274
Per cent. saved by mulches	....	24.27	52.69	53.23	63.41

During the third period of 42 days from Aug. 1 to Sept. 12 when the cylinders were out of doors in the open air and sun the amounts of water added were as follows:

	No mulch Per 100 days.	Mulch 1 in. deep. Per 100 days.	Mulch 2 in. deep. Per 100 days.	Mulch 3 in. deep. Per 100 days.	Mulch 4 in. deep. Per 100 days.
Black Marsh Soil:					
Tons per acre	588.0	355.0	270.0	256.4	252.5
Inches of water	5.193	3.12	2.384	2.265	2.230
Per cent. saved by mulches	....	39.54	54.08	56.39	57.06
Sandy Loam:					
Tons per acre	741.5	373.7	339.3	287.5	315.4
Inches of water	6.548	3.300	2.996	2.539	2.785
Per cent. saved by mulches	....	49.60	54.24	61.22	57.47
Virgin Clay Loam:					
Tons per acre	2,414	1,260	979.7	889.2	883.9
Inches of water	21.31	11.13	8.652	7 852	7.805
Per cent. saved by mulches	....	47.76	59.38	63.13	63.34

During this period of exposure out of doors it was necessary during times of rainy or threatening weather to place the covers on the cylinders, and doing this the actual period of exposure to evaporation was only 37 days, although the period covered 42 days.

It will be seen that these tables present the observed rates of loss of water per 100 days from three types of soil placed under like conditions, first when the surface is firm and smooth, and second when covered with ordinary soil mulches 1 inch, 2 inches, 3 inches and 4 inches deep. The whole period of observation has covered 180 days, and the mean rate of loss per 100 days for the three periods under the four conditions of surface is as given below:

Table showing the mean loss of water in tons per acre and per 100 days.

KIND OF SOIL.	DEPTH OF MULCH.				
	0	1 inch.	2 inches.	3 inches.	4 inches.
Black marsh soil	620.9	367.0	274.3	248.9	213.8
Sandy loam	724.1	397.1	288.8	269.2	251.8
Virgin clay loam	1,779.6	1,249.6	1,029.2	974.6	881.6

This table shows clearly that the effectiveness of the mulches increases rapidly with the depth for each of the three types of soil and that the loss of water has been much more rapid both from the unmulched and from each of the mulched surfaces of the virgin clay loam than from either of the other soils.

The rate of evaporation under the field conditions was greater than during the 80-day period in the laboratory with the three soils, and it was greater during the first period in the laboratory than it was during the second period. These relations should be expected because in the first and third periods the experiments started with wet mulches while at the beginning of the 80-day period the mulches were comparatively dry. Under the out-of-door conditions there was both a stronger wind movement and direct sunshine upon the soil.

Referring to Fig. 21, the total cross-section of the case was 962 sq. in., but the three rows of cylinders cut this down to 679.32 sq. in., or 4.71 sq. ft. and the mean air movement figured on this available section was at the rate of 1,918 feet per hour during the first period and 1,400 feet per hour for the second period. But it is probable that the major part of the air movement did take place above the tops of the cylinders and figuring the rate on this portion of the section the mean velocity per hour during the first period would be 3,386 ft. and during the second period 2,476 feet. Under the out-door conditions the air movement was probably much larger than in either of these cases, but as an offset against this difference and that of direct sunshine on the soil it is likely that the evaporation during the night was larger in the laboratory than out of doors.

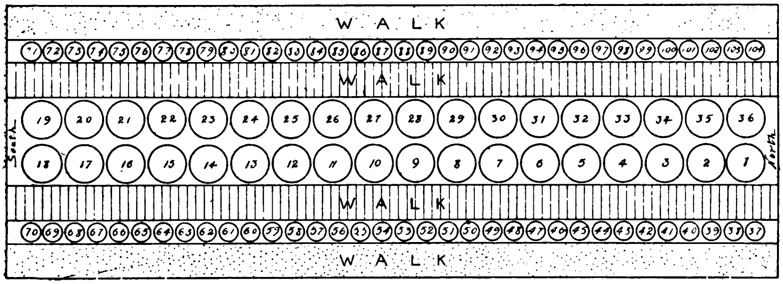

FIG. 22.—Showing the numbers and arrangement of plant house cylinders used in studying the effectiveness of mulches.

EXPERIMENTS IN THE PLANT HOUSE.

In these experiments much larger volumes of soil and greater depths of it were used than in the cases just described. For this work there were used 36 cylinders placed as represented in Fig. 22 and having a depth of 52 inches and a diameter of three feet. These cylinders, numbered from 1 to 36, were filled with the black marsh soil used in one set of the experiments just described, and contained on the average not far from a ton of the wet soil. With these large cylinders there were also used 54 smaller ones having the same depth and one-half the diameter, arranged as shown in the figure and numbered from 37 to 90. The soil used in these cases was the virgin clay loam of the last series of tests, and the mean total weight was not far from 675 pounds.

In both sets of these cylinders the soil used to fill them was taken from the surface 6 inches of the ground and was brought from the field in wagons and put into them in weighed lots at a time in regular rotation in order to secure as close a similarity between individual cases as possible, but this was done more than a year prior to the starting of the experiments here described and three crops of one kind or another had been grown upon the soils. In the bottom of each cylinder there is a line of 3 inch drain tile covered with coarse plastering sand upon which the soil was placed, and a drainage pipe closed by a cap leads from one end of the drain tile to provide rapid and thorough drainage when desired.

In order to insure as close an equality of moisture relations in the soil of the several cylinders as possible water was added until complete saturation was reached and the water stood above the surface. In this condition the soil remained about 60 hours. In the case of the small cylinders the saturation of the soil resulted in considerable settling of the surface, and in consequence of this, new soil was added in small lots at a time directly to the wet surface tamping with a flat circular iron disk weighing 5 lbs. until the level was brought to within ¾ of an inch of the top. No such settling occurred after wetting the black marsh soil and nothing was added to these cylinders.

At this stage the 36 large cylinders and the 54 small ones were divided into four groups as follows:

One set not to be cultivated and three other sets to be cultivated 1 inch, 2 inches, and 3 inches deep respectively. The cylinders which were to be cultivated were further grouped into those which were to be cultivated once in two weeks, once each week and twice each week.

In selecting the cylinders for each group an effort was made to have the members of each sub-group as widely and evenly distributed in the plant house as possible and the classification adopted is as follows:

1. Cylinders not cultivated are Nos. 2, 25, 30, 40, 50, 60, 70, 74 and 84.
2. Cylinders cultivated one inch deep:
   (a) Once in 2 weeks, 7, 12, 35, 39. 49, 59, 73, 83.
   (b) Once each week, 9, 14, 33, 43. 53, 63, 77, 87.
   (c) Twice each week, 5, 22, 27, 46, 56, 66, 80, 90.
3. Cylinders cultivated 2 inches deep:
   (a) Once in two weeks, 6, 21, 18, 26, 36, 38, 48, 58, 69, 72, 82.
   (b) Once each week, 3, 17, 20, 24, 29, 42, 52. 62, 68, 76, 86.
   (c) Twice each week, 10, 15, 16, 19, 32, 45, 55, 65, 67, 79, 89.
4. Cylinders cultivated 3 inches deep:
   (a) Once in two weeks, 1, 11, 31, 37, 47, 57, 71, 81.
   (b) Once each week, 8, 13, 34, 41, 51, 61, 75. 85.
   (c) Twice each week, 4, 23, 28, 44, 54, 64, 78, 88.

The positions of these cylinders are shown by numbers in Fig. 22.

After the cylinders had been allowed to stand during 10 days more the mulches were developed in the following manner:

In the case of the black marsh soils the surfaces were smoothed and then tamped with the five pound weight referred to and left in this condition where no mulches were developed In the other cases the soil was stirred to the desired depth with a four-tined potato fork upon whose tines a gauge was fixed so as to slide upon two pieces of gas pipe resting on the rim of the cylinder, thus securing the desired depth of mulch.

In the case of the small cylinders enough soil was removed to secure a level undisturbed surface one and one-fourth inches below the rim of the cylinder plus the depth of the desired thickness of mulch. Enough of the soil removed was then returned at once in a finely crumbled condition to the several cylinders to bring their surfaces to one and one-fourth inches below the rim.

The cylinders were all weighed and the experiment proper begun on Nov. 24, 1897, and continued without the addition of water to any of the soils during the first period of 30 days.

At this time, Dec. 24, after weighing, water was added to the surface soil of all cylinders to the amount of a rainfall of one-half an inch, and four days later all of the mulched surfaces were stirred using the four-tined potato fork in the manner described in preparing the mulches. All cultivations of these soils have been made in this way.

In starting the second period of the experiment the soils stood four days after wetting before cultivation. Thirty-two days from the first wetting and 28 days after the first cultivation of this period all cylinders were again given the equivalent of a rainfall of one-fourth of an inch; but following this wetting four days only cylinders cultivated once per week and twice per week had the soil stirred and the experiment was closed Feb. 1 after a period of 39 days.

The total observed losses during each of the two periods for the several cylinders are given in the following table.

Table showing losses of water from plant house cylinders during 30 days from Nov. 24 to Dec. 24, and during 39 days from Dec. 24th to Feb. 1st.

No of cylinder.	1st period of 30 days.	2nd period of 39 days.	No. of cylinder.	1st period of 30 days.	2nd period of 39 days.	No. of cylinder.	1st period of 30 days.	2nd period of 39 days.
1	23.00	37.60	31	21.60	36.01	61	13.50	16.90
2	27.00	50.60	32	22.00	37.10	62	13.00	18.40
3	23.50	38.60	33	18.50	33.98	63	11 75	17.40
4*	31.50	41.10	34	22.60	35.96	64	12.75	16.15
5	19.00	41.10	35	31.00	34.60	65	11.50	17.90
6	20.50	37.10	36	19.00	34.60	66	12.00	16.90
7*	20.50	39.10	37	14 00	18.15	67	11.25	16.15
8	24.00	44.60	38	12.00	18.90	68	12.00	18.90
9	20.40	40.35	39	13.50	19.40	69	15.75	19.90
10	22.50	39.10	40	14.25	21.15	70	19.75	30.15
11	20.50	40.10	41	8.25	16.65	71	18.75	25.15
12*	20.00	41.60	42	11.50	16.90	72	19.75	23.15
13	23.50	39.10	43	12.25	18.15	73	14.75	18.15
14	21.00	37.60	44	10.50	16.40	74	18.50	25.90
15	26.00	37.60	45	11 25	16.40	75	14.75	18.65
16		38.60	46	12.00	16.40	76	15.50	19.40
17*	24.50	40.10	47	13.25	18.15	77	14.25	16.65
18	18.50	37.60	48	13.25	17.90	78	13.00	16.90
19	19.00	36.60	49	11 00	17.65	79	12.75	17.15
20	17.00	37.60	50	14.50	20.15	80	11.25	16.40
21	17.40	36.42	51	11.25	17.40	81	13.50	18.15
22	19.90	37.60	52	13 25	16.65	82	13.75	17.90
23*	25.50	38.60	53	15.00	18.65	83	12.75	15.65
24	20.20	37.10	54	11.25	15.15	84	14.75	22.65
25	26.10	40.60	55	13.25	16.90	85	13.50	17.90
26	21.00	36.60	56	14.00	19.90	86	13.25	16.65
27*	23.30	35.10	57	14.90	18.15	87	12.00	16.40
28	24.50	36.94	58	13.25	19.15	88	12.00	14.40
29	13.50	36.07	59	13.75	17.65	89	11.00	17.65
30	29.30	40.60	60	17.00	24.40	90	12.00	16.90

* The losses from these cylinders were not used in our calculations because the cylinders appeared to leak.

In studying the losses of moisture from these two soils under the plant house conditions with reference to the frequency and depth of cultivation they will be found as follows:

For the virgin clay loam.

	Not cultivated.	Once in 2 weeks.	Once per week.	Twice per week.
	Per acre.	Per acre.	Per acre.	Per acre.
Cultivated one inch deep:				
The loss in tons per 100 days was.......	724.1	551.2	545.0	527.8
The loss in inches per 100 days was.....	6.394	4.867	4.812	4.662
The percentage of water saved was	....	23.88	24.73	27.10
Cultivated 2 inches deep:				
The loss in tons per 100 days was.......	724.1	609.2	552.1	515 4
The loss in inches per 100 days was.....	6.394	5.380	4.875	4.552
The percentage of water saved was	....	15.88	23.76	28.81
Cultivated 3 inches deep:				
The loss in tons per 100 days was.......	724.1	612.0	531.5	495.0
The loss in inches per 100 days was.....	6.394	5.280	4.694	4.371
The percentage of water saved was	....	15.49	26.60	31.64

For the black marsh soil.

	Not cultivated.	Once in 2 weeks.	Once per week.	Twice per week.
	Per acre.	Per acre.	Per acre.	Per acre.
Cultivated one inch deep:				
The loss in tons per 100 days was......	319.0	248.4	255.9	262.6
The loss in inches per 100 days was...	2.816	2.194	2.260	2.319
The percentage of water saved was...	....	22.13	19.78	17.65
Cultivated two inches deep:				
The loss in tons per 100 days was	319.0	249.1	249.8	268.9
The loss in inches per 100 days was...	2.816	2.200	2.206	2.374
The percentage of water saved was...	....	21.93	21.70	15.72
Cultivated three inches deep:				
The loss in tons per 100 days was	319.0	266.2	282.6	274.5
The loss in inches per 100 days was...	2.816	2.351	2.495	2.424
The percentage of water saved was ..	....	16.53	11.41	13.94

It will be seen from the table of evaporations from the clay loam that with each of the three depths of cultivation the percentage of moisture saved over that which was lost from the not cultivated ground increased with the frequency of cultivation; that is to say, if one is cultivating ground of this character one inch deep then the largest saving of moisture results from stirring the soil twice per week, and when this saving over the cultivation once in two weeks is expressed in tons per acre the amount is 23.29 tons per 100 days, or .23 tons per day and 1.6 tons per week per acre.

If he is cultivating three inches deep twice per week as against three inches deep once in two weeks then the saving of moisture is 116.9 tons per 100 days; 1.17 tons per day and 8.18 tons per week per acre. Or if the comparison is made between cultivation three inches deep twice per week and no cultivation then the saving of moisture is 229.1 tons per 100 days; 2.29 tons per day and 16.03 tons per acre per week.

If we refer to the table for the losses of moisture which have occurred under the cultivation once in two weeks for each depth it will be seen that the greatest saving appears to have resulted from the cultivation one inch deep, and the least saving when the cultivation was three inches deep. These relations may possibly be an expression of a principle in tillage, but further observations will be required to establish it. It appears possible that when soil stirred three inches deep has remained quiet during a fortnight the lower portion may have become so moist and firmed that when turned up by deep tillage it carries to the air more moisture than could have escaped through the drier soil which is stirred but one inch deep; and if this is true it follows that for long interval cultivations, on the kind of soil in question, the shallower depths of stirring are to be preferred to the deeper. The data here presented, however, are not sufficient to warrant such a conclusion.

When the results from the black marsh soil are considered they appear to stand in contradiction to those of the same soil in the first series of experiments and from those of the virgin soil in both series. This difference, however, is much more apparent than real, and is due (1) to the fact the black soil has so very high a water capacity, and (2) to determining the losses by weighing, making no distinction between the losses from the mulches themselves and from the body of the soil. It is evident that if the 1-inch, 2-inch and 3-inch mulches became equally dry that three times the amount of water would be lost from the 3-inch as from the 1-inch mulch, and when these losses are determined by weighing the observed changes would make it appear that more water was lost through the deepest mulches when in reality it is only lost from the mulches themselves as a result of stirring and the larger volume of soil. This source of error was not recognized until the results had been worked out, and no correction was then possible. It is certain, however, that the real effectiveness of the mulches in the second series of observations is larger than the table shows, because the drying out of the mulches is counted as water lost from the body of the soil, which is not true. It is also probably true that both series of observations are in strict accord in showing that the effectiveness of mulches increases with the depth.

If we bring together the per cents. of water saved from these soils under the different treatments they will stand as given in the table below:

Table showing the percentage of water saved from two soils under different depths and different frequencies of cultivation computed on the loss under no cultivation.

CULTIVATIONS.	Period.	BLACK MARSH SOIL.			VIRGIN CLAY LOAM.		
		Cultivated once in two weeks.	Cultivated once per week.	Cultivated twice per week.	Cultivated once in two weeks.	Cultivated once per week.	Cultivated twice per week.
One inch deep	1st	23.57	27.30	29.21	20.19	20.67	25.53
	2d	21.24	15 08	10.42	26.46	27.50	28.14
	Whole..	22.13	19.78	17.65	23.88	24.73	27.10
Two inches deep..	1st......	29.82	32.41	18.55	11.06	20.49	28.09
	2d......	17.01	15.00	13.96	19.07	25.97	29.26
	Whole..	21.93	21.70	15.72	15.86	23.76	28.81
Three inches deep	1st	21.00	14.93	10.81	10.65	25.53	27.67
	2d	13.74	9.20	15.92	18.77	27.30	34.36
	Whole..	16.53	11.41	13 94	15.49	26.60	31.64

In the next table the losses are given in tons per acre, and in inches for each treatment for each period.

Table showing the losses of water through soil mulches of different kinds and depths with different frequencies of cultivation, given in tons per acre and inches per 100 days.

		BLACK MARSH SOIL.				VIRGIN CLAY LOAM.			
		Not cultivated.	Cultivated once in two weeks.	Cultivated once per week.	Cultivated twice per week.	Not cultivated.	Cultivated once in two weeks.	Cultivated once per week.	Cultivated twice per week.
Not cultivated.		Tons.				Tons.			
	30 days.	282.2	....	....	....	676.3	....	....	....
	39 days.	347.1	....	....	....	760.7	....	....	....
	Total.	319.0	....	....	....	724 1	....	....	....
		Inches.				Inches.			
	30 days.	2 493	....	....	....	5.971	....	....	....
	39 days.	3.066	....	....	....	6.717	....	....	....
	Total.	2.816	....	....	....	6.394	....	....	....
Cultivated 1 inch deep.			Tons.	Tons.	Tons.		Tons.	Tons.	Tons.
	30 days.	....	215.8	205.2	199.8	....	540.4	536.2	503.4
	39 days.	....	273.4	294.8	311.0	....	559.4	551.5	546.6
	Total.	....	248.4	255.9	262.6	....	551.2	545.0	527.8
			Inches.	Inches.	Inches.		Inches.	Inches.	Inches.
	30 days.	....	1.905	1.812	1.764	....	4.772	4.735	4.445
	39 days.	....	2.414	2.603	2.746	....	4.940	4.870	4.827
	Total.	....	2.194	2.259	2.319	....	4.867	4.812	4.662
Cultivated 2 inches deep.			Tons.	Tons.	Tons.		Tons.	Tons.	Tons.
	30 days.	....	198.1	190.8	229.9	....	601 2	537.4	486.1
	39 days.	....	288.1	295.0	298.6	....	615.6	563.1	538.2
	Total.	....	249.0	249.8	268.9	....	609.2	552.1	515.4
			Inches.	Inches.	Inches.		Inches.	Inches.	Inches.
	30 days.	....	1.749	1.685	2.030	....	5.309	4.745	4.292
	39 days.	....	2.544	2.605	2.637	....	5.437	4.975	4.752
	Total.	....	2.199	2.206	2 374	....	5.380	4.875	4.552
Cultivated 3 inches deep.			Tons.	Tons.	Tons.		Tons.	Tons.	Tons.
	30 days.		222.9	240.1	251.7	....	603.9	503.4	488.9
	39 days.	....	299.4	315.2	291.8	....	617 9	553.0	499.3
	Total.	....	266.2	282.6	274.5	....	612.0	531.5	495.0
			Inches.	Inches.	Inches.		Inches.	Inches.	Inches
	30 days.	....	1.969	2.120	2.223	....	5.333	4.445	4.31.
	39 days.	....	2.644	2.784	2.577	....	5.457	4.883	4.417
	Total.	....	2.351	2.496	2.424	....	5.280	4.694	4.370

EVAPORATION IN THE PLANT HOUSE AS SHOWN BY PICHE EVAPOROMETERS.

In order to have a more definite idea of the atmospheric conditions under which the foregoing results were obtained there were suspended above the space between the cylinders 1–2 and 36–35 at the north end of the plant house and above the space between 17–18 and 19–20 at the south end, two evaporometers. The disks of the instruments hung 3½ inches above the level of the rims of the cylinders, and the sheets of filter paper used had a diameter of 10 c. m., and the evaporating surface exposed, excluding the area covered by the measuring cylinders, was 12.26 sq. in. for the north, and 12.25 sq. in. for the south instrument.

There was also kept a record of the rate of evaporation from a wet sand surface in cylinder 91, which was filled with coarse plastering sand to within one foot of the top and then covered with 12 inches of a finer screened sand. At one side of the cylinder was set, flush with the top, a length of 3 inch drain tile painted outside and in with asphalt paint to prevent capillarity through the walls and water was added twice weekly, each time supplying it until the surface of the sand in the cylinder just began to show the rise of water through it, and the opening of the tile was kept covered to prevent evaporation from the water surface.

The rates of evaporation as measured by the evaporometers and from the constantly wet sand surface are given in the table which follows:

Table showing rate of evaporation from two Piche evaporometers and from a wet sand surface.

	Total evaporation in c.c.	Average daily evaporation in c.c.	Evaporation surface in sq. in.	Evaporation per 100 days in tons.	Evaporation per 100 days in inches.
North evaporometer for 30 days	766.1	25.54	12.26	Per acre. 1,437.0	12.70
South evaporometer for 30 days	941.3	31.38	12.25	1,768.0	15.62
Sand surface for 30 days	5,609.0	186.97	210.73	536.0	4.734
North evaporometer for 39 days	1,123.8	28.82	12.26	1,622.0	14.32
South evaporometer for 39 days	1,360.9	34.89	12.25	1,966.0	17.36
Sand surface for 39 days	10,995.0	281.92	240.73	808.2	7.137

There was also suspended at the level of the tops of the cylinders, one near the south end of the plant house and the other near the north end, two Richard thermographs by means of which continuous records of the air temperature were kept and these are given in a table beyond.

It will be of general interest to note here how the rate of evaporation, as measured by a Piche evaporometer compares with the losses of water from soil surfaces under different conditions and there is brought together for purposes of comparison the data in the following table:

Table showing the comparative rates of evaporation from a Piche evaporometer and soil surfaces of different characters.

	Mean evaporation per acre per 100 days.	
	In tons.	In inches.
Piche evaporometer	1711.0	15.105
Saturated sand surface	690.1	6.094
Unstirred virgin clay loam	724 1	6.394
Virgin clay loam cultivated 1 inch deep once in two weeks	551.2	4.867
Virgin clay loam cultivated 2 in. deep once in two weeks	609.2	5.380
Virgin clay loam cultivated 3 in. deep once in two weeks	612.0	5.280
Black marsh soil not cultivated	319.0	2.816
Black marsh soil cultivated 1 in. deep once in two weeks	248.4	2.194
Black marsh soil cultivated 2 in deep once in two weeks	249.0	2.199
Black marsh soil cultivated 3 in. deep once in two weeks	266.2	2.351

It must be observed that the Piche evaporometer as used by us was not placed under conditions which were identical with those under which the U. S. Weather Bureau have obtained the results they have published and hence it will not be possible to compute from the Weather Bureau tables probable rates of evaporation from soil surfaces in different portions of the United States.

The records of the temperature of the air under which the results of the last table were secured are given in the table which follows:

Average hourly temperatures for the period of 30 days, for the period of 39 days and for the whole period of 69 days of mulching-experiment in plant house.

HOUR.	1ST PERIOD 30 DAYS.		2ND PERIOD 39 DAYS.		WHOLE PERIOD 69 DAYS.	
	North thermometer.	South thermometer.	North thermometer.	South thermometer.	North thermometer.	South thermometer.
Noon	69.19	70.19	69.60	73.12	69.42	72.14
1	68.64	71.31	70.79	74.33	69.85	73.03
2	68.43	69.32	71.54	73.04	70 20	71.40
3	65.18	64.97	67.80	68.99	66.08	67.25
4	62.12	61.66	63.97	64.21	63.01	63.10
5	59 32	59.88	60.51	60.93	60.01	60.46
6	59.17	59.46	59.23	60.02	59.21	59.77
7	59.37	59.35	58.86	60.27	59.09	58.13
8	58.82	59.44	58.88	60.15	58.85	59.85
9	58.51	59.20	58.67	59.83	58.61	59.57
10	58.17	58.84	58.36	59.61	58.28	59.29
11	57.15	58.15	57.90	58.45	57.88	58.33
Midnight	57.55	58 03	57.71	58.28	57.65	58.19
1	57.42	57.83	57.51	58.40	57.48	58.17
2	57.26	57.10	57.52	58.46	57.41	57.90
3	57.09	57.31	57.42	58.14	57.28	57.80
4	56.79	57.08	57.34	58.04	57.11	57.64
5	56.26	56.90	56.91	57.78	56.63	57.41
6	55.69	56.62	56.65	57 14	57.69	56.93
7	56.00	56.34	56.44	57.05	56.24	56.76
8	56.66	58.06	56.44	57.31	56.54	57.62
9	59.03	60.30	58.44	60.80	58.69	60.58
10	64.61	64.36	65.03	63.97	64.85	64.14
11	67.06	69.53	69.00	71.93	68.17	70.81
Average	60.22	60.88	60.94	62.09	60.68	61.51
Ave. of the two.	60.55		61.51			

ONE YEAR'S WORK DONE BY A 16-FOOT GEARED WINDMILL.*

F. H. KING.

The experiments here described furnish the first complete and careful record of a full year's work done by any windmill where both the work done and the wind movement have been automatically recorded hour by hour for a whole year.

The want of accurate data such as is here presented has long been felt, and in view of this fact great pains has been taken to so arrange and present the data that they will be easily accessible to both practical and scientific men.

The variable and unsteady force of the wind has always been the most serious hindrance to the use of the windmill as a motive power and so, in order that the real character and magnitude of this variability in terms of work may be seen for all hours of the day and for all days of the year, the records of the whole year have been brought into a table in such a way that a simple inspection will show just what this windmill was able to do on any hour or day or succession of days throughout the year. The table shows just how frequently and during how long intervals the windmill was able to do no work, it shows when and how consecutively it could do heavy work and it shows how persistently a moderate amount of work could be done by it. These are the essential facts which the practical man needs to know, and they are in the form which is most readily accessible to him. At the same time the data are in such shape that those who wish to use them for scientific purposes will be able to do so. Table I., here referred to, will be found in the appendix.

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* Lack of room in this Report makes it possible to give only a portion of the data obtained, the balance may be found in Bull. 68 of this Station.

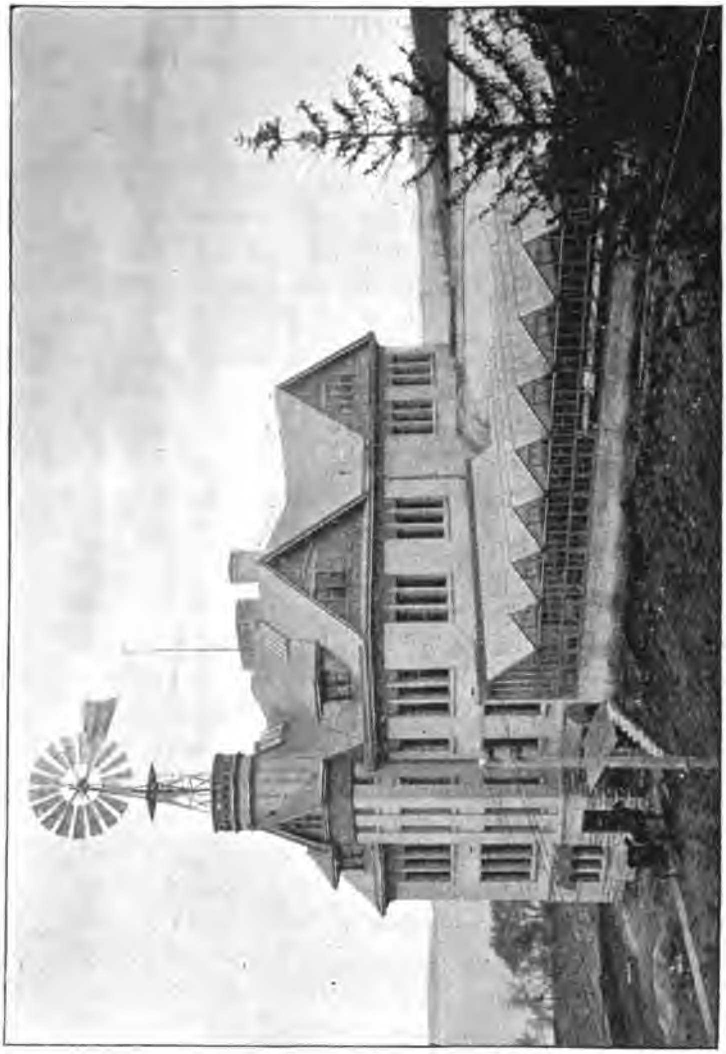

FIG. 23.—Showing 16-foot geared steel Aermotor windmill on the Agricultural Physics Laboratory, together with the anemometer.

THE WINDMILL USED.

The windmill used to secure the data here presented is a 16-foot geared steel power mill, purchased of the Aermotor Co., of Chicago, Ill., and erected by them on the tower of the Agricultural Physics laboratory, as shown in the photo-engraving Fig. 23. The mill stands on a steel tower with its axis 22 feet above the deck, 82 feet above the ground outside the building and about 106 feet above lake Mendota, which can be seen in the background about 1,000 feet distant. The building is on the north slope of a hill, near its summit.

It was impracticable to arrange the pumps and other machinery in the laboratory in such a way as to transmit the power directly to the driving shaft and an offset had to be made. The manufacturers first arranged that this should be done with a sprocket wheel and chain but the plan proved unsatisfactory on account of the high speed often attained, and 14 inch flanged pulleys carrying a 6-inch rubber belt were substituted instead. At the bottom of the 1-inch driving shaft a foot gear transmits the power to a 1½ inch horizontal shaft from which the pumps and other machinery are driven.

It will be observed that this arrangement has necessitated two transfers of power besides that in the head of the mill itself. This statement should be kept in mind when studying the results secured by the mill as they have necessarily placed it at some disadvantage which under ordinary circumstances would be avoided.

THE PUMPS USED.

The work of the mill for the year has been done on one or more of four pumps whose position and general arrangement may be seen in Fig. 24, and which belong to four patterns as follows:

1. A reciprocating pump with 14-inch piston arranged to be worked on 6, 9, or 12 in. strokes as desired, and made partially double-acting by using a large wooden plunger

rod capable of displacing with the down stroke nearly one-half of the water raised by the up stroke. This pump when in service was on the 9-inch stroke.

2. The second pump used is one of the bucket types manufactured by Seaman and Shuske, St. Joseph, Mo., and has a normal capacity of 120 gallons per minute, the buckets carrying one gallon of water each.

3. The other two pumps are of the centrifugal types, one a No. 2 Gould, and the other the smallest size of the Menge pattern. These were not found satisfactory for windmill service and were only used in exceptional cases when the wind was high and steady.

Nearly all of the work done by the mill was accomplished with either the reciprocating or the Seaman pump or with the two pumps combined. Occasionally it was necessary to give the mill the Menge pump with the other two in order to fully load it down.

The Seaman pump required the least power to run it and had the smallest capacity of the three and was always given to the mill in light winds. When the wind was stronger, the reciprocating pump was given to the mill and when still stronger the two pumps were worked together.

With this combination we have been able to secure more work than would have been possible with either pump alone. But it has not been possible with this arrangement to secure the maximum amount of work the mill is able to do. It frequently happened when the mill was left with one pump that during the night the wind became strong enough to carry two, but it did not get them until the next morning. So, too, when in the evening the wind was strong enough to work the two pumps and it was left with them, the wind would go down until the two could not be handled, when if but one had been left this could have been worked all right.

The belts by which the pumps were driven were so arranged as to be shifted upon supports which removed all tension from the driving shaft when these were not in service.

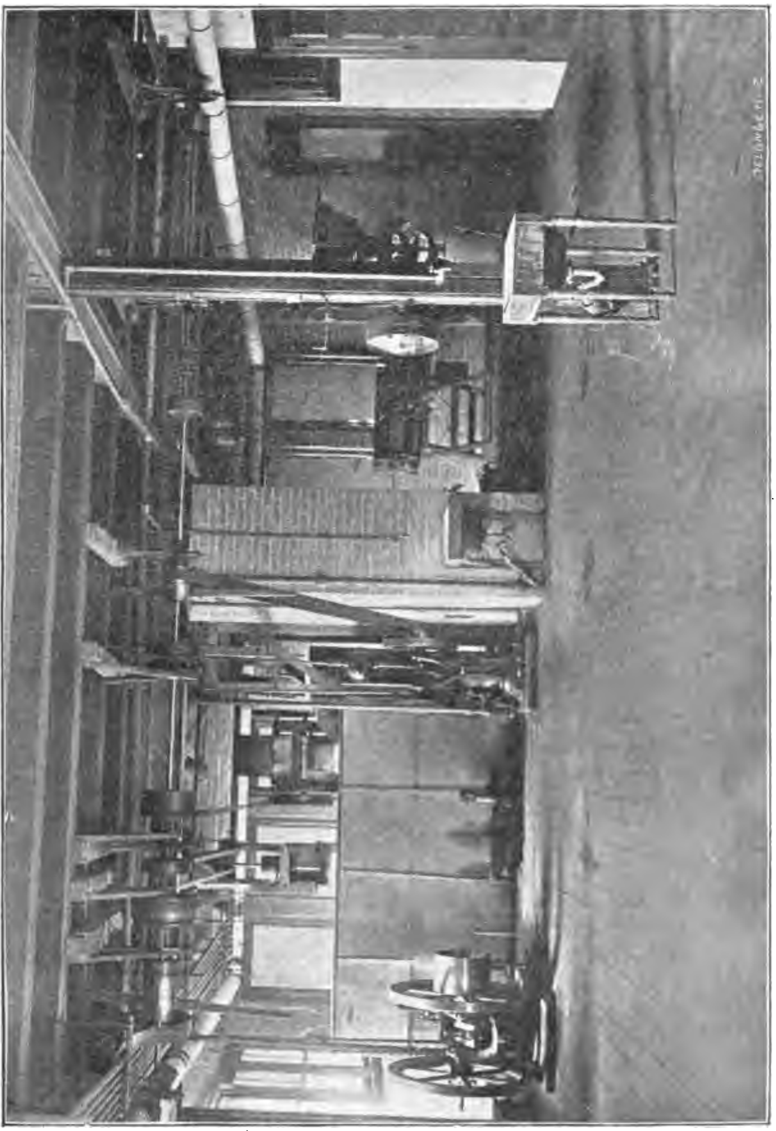

FIG. 24.—Showing the power laboratory with driving shaft over head; feed mill in front and to the right; and measuring tank, four pumps, and two engines at the left.

METHOD OF MEASURING THE WORK DONE.

To measure the work done by the windmill it was arranged so that water could be lifted from a reservoir having an area of 285 sq. ft., and be discharged into a measuring tank holding 141.2 cu. ft., as shown in Figs. 24 and 25. When the measuring tank was filled to the top of the siphon it was automatically emptied, and the time required for doing this when no water was being pumped was 45 seconds.

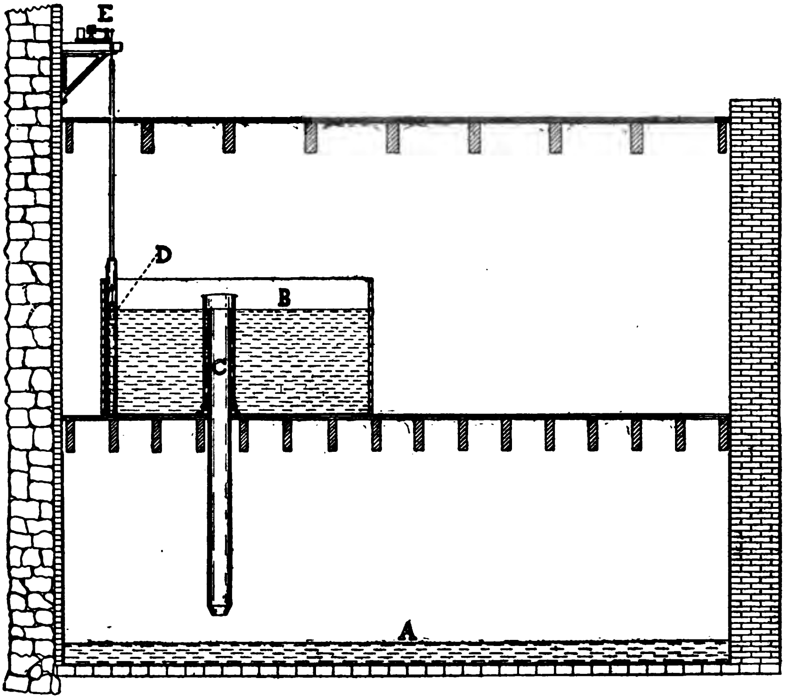

FIG. 25.—Showing reservoir A from which water was pumped; measuring tank B; emptying syphon C; float D, and recording instrument E.

By means of a float shown at D, Fig. 25, arranged to work the pen on a chronograph, a record was secured of the number of times the tank was emptied each day and of the interval between each emptying.

The mean height to which the water was lifted was, during March and April, 1897, 10.5 feet, but after that date the lift was increased to 12.85 feet.

Through the courtesy of the U. S. Weather Bureau we were loaned a self-recording anemometer of the Robinson type, and this was raised above the roof of the laboratory on a piece of gas pipe until its axis was on a level with that of the windmill, as shown in Fig. 23.

AMOUNT OF WATER PUMPED DURING THE YEAR.

The experiment was started at noon on March 6, 1897, and closed at noon of the same date, 1898, and the number of times the measuring tank was emptied each hour of every day in the year is given in Table I, in the appendix together with the miles of wind which passed the mill during the corresponding times.

There have been times during the year when for various reasons the mill was not doing service when there was wind enough to have enabled it to have done so, and such gaps in the records have been filled in the following manner: After the data was all tabulated by hours of the day a new table was made in which the number of tanks of water pumped were all classified under the various wind velocities which occurred and in this way the mean number of tanks pumped per hour under the several wind velocities was found; then these mean values were used to fill the blanks in the table and make a complete record for the year.

The table which follows shows that the total amount of water pumped during the 365 days was 24,433 tanks, each holding 141.2 cu. ft. This is at the mean rate of 2.789 tanks each and every hour of the day, or 393.8 cu. ft. per hour and 6.562 cu. ft. per min. Expressed in another way the water pumped during the year is sufficient to cover 79.1 acres 12 inches deep, or at a rate of 2.6 acre-inches per day for the full year.

Table showing the total number of tanks of water pumped each hour of the day for each month, and the total wind movement in miles for the same time.

Month.	Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Midnight
March..	425.0	446.0	438.0	436.5	411.0	382.5	378.5	365.5	332.0	323.0	322.0	298.0	319.0
	113.4	112.8	111.8	101.6	94.5	80.1	61.8	67 0	60.3	46.0	62.7	50.1	50.9
April ...	521.5	512.5	476 0	476.0	408.0	436.5	392.5	394.0	368.0	424.0	431.5	464.0	412.0
	157.0	133.8	138.0	137.2	126.7	108.2	78.7	74.6	63.3	85.8	103.5	108.5	90.3
May	446.5	453.5	437.0	440.5	411.5	361.0	346.0	366.5	378.0	373.0	375.0	367.0	342 0
	115.6	122.4	116.2	106.3	93.8	77.6	52.7	66.7	68.9	68.7	74.5	72.5	73.9
June....	320.0	326.5	310.5	320 0	320.0	305.5	300.5	292.5	299.5	310.0	267.5	267.0	292.5
	73.4	78.0	67.5	66.2	61.8	38.0	44.0	48.0	51.0	51.0	38.0	47.0	40.0
July....	328.0	351.5	347.5	351.5	325.5	306.0	273.0	253.0	261.5	276.5	258.0	228.9	236.5
	75.1	71.7	64.5	67.7	57.5	58.2	34.7	22.4	23.5	26.0	29.2	25.7	29.6
Aug.....	354.0	352.0	358.0	354.0	326.0	305.0	282.0	255.5	241.0	239.0	247.0	242.0	270.5
	76.0	79.3	82.9	75.4	64.4	54.0	35.0	35.0	34.0	33.0	34.0	38.0	36.0
Sept....	339.0	354.0	362 0	351.0	331.0	276.0	246.0	256.0	271.0	264.0	272.0	252.0	251.0
	89.6	101.6	96.7	93.1	82.1	49.4	30.6	30.3	37.8	37.0	40.3	38.7	44.4
Oct.....	392.0	401.0	389.0	376.0	359.0	318.0	341.0	355.0	342.0	350.0	329.0	314.0	325.0
	107.2	114.1	111.3	103.9	96.9	65.0	68.4	83.0	74.4	83.3	82.3	72 3	74.5
Nov.....	436.0	443.0	439.0	425.0	388.0	315.0	359.0	373.0	368.0	385.0	373.0	365.0	371.0
	151.9	135.0	139.0	136.0	116.0	112.0	110.0	114.0	110.0	110.0	100.0	94 0	92.0
Dec.....	395.0	389 0	359.0	331.0	326.0	329 0	334.0	339.0	351.0	359.0	348.0	348.0	364.0
	133.2	119 8	102.7	80.0	79.8	84.3	89.4	84.3	85.2	83.0	95.1	105.0	101.0
Jan.....	388 0	409.0	376.0	356.0	331.0	317.0	352.0	362.0	326.0	334.0	325.0	306.0	330.0
	117.5	126.9	113.7	91.5	79.1	77.3	85.2	86.1	84.4	76.6	71.8	73.4	74.1
Feby....	406.0	412.0	401.0	408.0	381.0	345.0	365.0	365.0	347.0	363.0	368.0	365.0	392.0
	119.2	131.1	135 0	122.9	116.4	103.2	99.8	102.6	100.9	108.7	106.3	109.3	115.1
	4741.0	4850.0	4693.0	4625.5	4318.0	4026.5	3969.5	3977.0	3885.0	4000.5	3916.0	3816.9	3905.5
	1329.1	1346.5	1279.3	1181.8	1069.0	907.3	790.3	814.0	793.7	809.1	837.7	834.5	821.8
Correc'n	95 2	98,5	92.1	77.6	67.1	53.0	42.2	43.6	45.8	49.0	49.8	49.5	46.1
Totals	1424.3	1445.0	1371.4	1259.4	1336.1	960.3	832.5	857.6	839.5	858.1	887.5	884.0	867.9

Month.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Totals.
March.......	354.5	344.0	352.0	347.0	433.0	331.0	363.5	383.5	410.0	427.0	388.0	8765.0
	64.9	54.9	55.7	56.9	53.3	64.8	75.1	74.0	85.1	95.3	84.4	1777.4
April.........	414.5	410.0	408.0	410.5	404.0	429.5	453.5	410.0	488.5	493.5	475.0	10417.0
	95.1	89.7	89.9	87.6	84.8	92.6	120.2	124.8	139.4	148.0	150.8	2648.5
May	334.5	324.5	329.5	347.5	353.5	356.0	389.5	397.0	409.5	435.5	410.0	9472.0
	75.4	68.8	65.6	77.5	78.8	76.5	89.6	104.8	102.4	96.4	89.4	2035.6
June	269 0	278.5	275.5	261.5	269.0	281.0	353.5	322.5	310.0	291.5	297.0	7149.0
	36.0	29.0	27.4	20.4	35.0	63.0	76.0	80.0	63.0	58.0	51.0	1242.7
July..........	220.0	215.5	211.0	208.0	218.0	227.0	247 5	258.0	286 0	311.0	319.5	6412.0
	27.3	27.0	18.9	18.0	21.9	27.7	37.3	37.1	47.9	60.1	64.0	973.0
August......	232.0	220.5	243.5	273.0	259.0	275.0	239.0	269.0	289.5	306.5	298.0	6702.0
	26.0	30 0	37.2	42.2	31.0	36.0	44.0	48.0	57.0	62.0	60.4	1150.8
Sept..........	263.0	265.5	249.5	255 0	254.0	261 0	266.0	258.0	289.0	310.0	301.0	6591.0
	44.1	45.0	43.4	61.4	45.2	52.8	49.8	53 9	62.8	73.4	75.1	1378.5
Oct...........	316.0	309.0	307.0	284.0	265.0	288.0	273.0	312.0	318.0	351.0	349.0	7934.0
	72.4	69.2	66.1	55.0	45.7	57.3	47.5	66.9	72.8	89.5	90.4	1869.4
Nov...........	372.0	388.0	412.0	408.0	408.0	416.0	416.0	424.0	448.0	434.0	438.0	9303.0
	102.0	107.0	102.0	96.0	95.0	108.0	126.0	129.0	142.9	148.9	145.6	2822.3
Dec...........	378.0	377.0	372.0	352.0	330.0	358.0	338.0	340.0	349.0	370.0	380.0	8557.0
	102.0	104.5	103.0	91.6	85.9	99.9	83.0	94.1	99.0	115.2	110.5	2331.5
Jan...........	350.0	354.0	334.0	325.0	339.0	348 0	335.0	365.0	384.0	389.0	374.0	8474.0
	78.4	76.7	76.6	70.0	70.0	83.8	95.7	96.2	95.1	111.5	100.5	2112.7
Feby..........	405.0	396.0	419.0	397.0	384.0	383.0	384.0	373.0	390 0	382.0	348.0	9120.0
	117.1	107.9	106.5	95.2	92.3	97.8	112.1	112.7	118.6	115.5	100.0	2646.2
	3908.5	3882.5	3913.0	3868.5	3916.5	3953.5	4058.5	4112.0	4371.5	4501.0	4377.5	98905.0
	840.7	809.7	792.3	772.4	738.9	860.2	936.3	1021.5	1086.0	1173.8	1122.1	22988.0
Correction*..	50.8	47.1	44.1	41.6	40.2	52.6	63.5	66.6	72.3	82.8	73.9	....
Totals.....	891.5	856.8	836.4	814.0	779.1	912.8	1019.8	1088.1	1158.3	1256.6	1196.0	24433.0

* Approximate correction for water pumped during the time when the tank was being emptied.

In this table the numbers at the head of the colmuns are the hours of the day. The lines of numbers opposite the name of the month express the total number of miles of wind for the hour of the day at the head of the column, while the other lines express the number of times the tank was emptied during each hour of the day.

In the footings of the table the upper line is the total number of miles of wind during each hour of the day for the full year; the second line is the total number of tanks emptied: the third line is an approximate correction for the water pumped during the time when the tank was being emptied, while the last line is the total water pumped each hour of the day for the year.

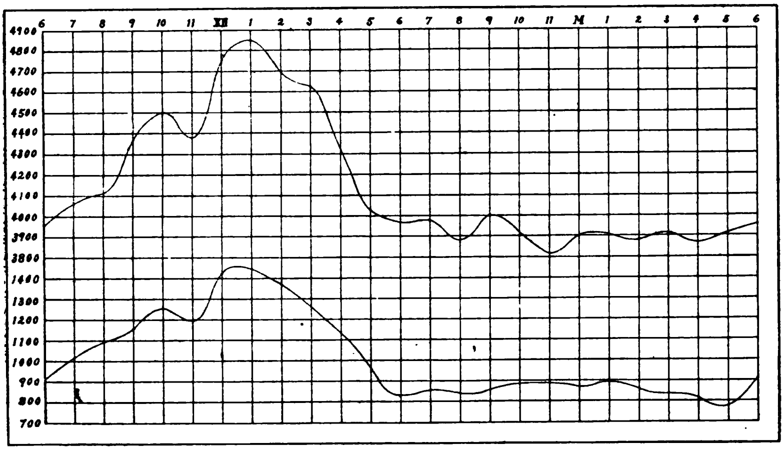

FIG. 26 —Showing the relation between the number of miles of wind during each hour of the day and the number of tanks of water pumped. The upper curve is for the miles of wind and the lower curve for the tanks of water pumped.

The largest amount of water pumped during any single day in the year was 39,540.2 cu. ft., which is a rate of 27.04 cu. ft. per min. There were times occasionally when high and steady winds lifted water so fast that the siphon failed to empty, so that the record above does not necessarily give the maximum amount of water lifted on any day but still it is very close to the true value. Fig. 26 shows graphically the relation between the miles of wind and the water pumped.

THE CAPACITY OF THE WINDMILL MEASURED IN TEN-DAY PERIODS.

The chief difficulty regarding the windmill as a motor is the great variability of the wind velocity which makes it necessary in the case of irrigation by pumping to provide storage for the water pumped so that it may be used in times of insufficient wind, if needed.

As irrigation may often be desirable at intervals of once in ten days, the work done in pumping by the windmill has been condensed into consecutive 10-day periods and given in the table below expressed in acre-inches or the amount needed to cover an acre of ground with water one inch deep lifted 10 feet high.

It will be seen from this table that the smallest amount of water lifted ten feet high in 10 days was enough to cover 9.87 acres one inch deep, and this occurred from July 28 to August 7, at the time when water for irrigation is most needed. The largest amount pumped occurred during the 10 days from Feb. 13 to 23 and was enough to cover 75.73 acres one inch deep.

Table showing computed amount of water lifted 10 feet high during consecutive 10-day periods for one full year expressed in acre-inches.

Date.	Water pumped.	Date.	Water pumped.	Date.	Water pumped.
	Acre-in.		*Acre-in.*		*Acre-in.*
Feb. 28-Mch. 10...	33.540	July 8-18..........	21.53	Nov. 15-25........	52.77
Mch. 10-20.........	36.620	July 18-28.........	29.73	Nov. 25-Dec. 5....	47.46
Mch. 20-30.........	52.77	July 28-Aug. 7....	9.87	Dec. 5-15..........	39.52
Mch. 30-Apr. 9....	47.01	Aug. 7-17.	36.26	Dec. 15-25........	31.18
Apr. 9-19	54.11	Aug. 17-27.........	20.20	Dec. 25-Jan. 4....	51.22
Apr. 19-29.........	63.05	Aug. 27-Sept. 6....	21.27	Jan. 4-14.........	33.92
Apr. 29-May 9.....	59.97	Sept. 6-16.........	18.00	Jan. 14-24........	29.16
May 9-19..........	28.69	Sept. 16-26........	40.42	Jan. 24-Feb. 3...	59.36
May 19-29.........	51.38	Sept. 26-Oct. 6....	23.79	Feb. 3-13.........	33.45
May 29-June 8....	40.54	Oct. 6-16..........	55.07	Feb. 13-23........	75.73
June 8-18..........	27.59	Oct. 16-26..........	18.45	Feb. 23-28........	16.20
June 18-28.........	13.82	Oct. 26-Nov. 5....	36.71		
June 28-July 8....	26.68	Nov. 5-15..........	49.49		

The mean amount of water pumped during the 100 days from May 29th to Sept. 6 was 24.549 acre-inches per 10 days, and as this is the season when the water is most needed in the United States it shows about what the capacity of such a plant is for irrigating purposes where the lift is 10 feet. With a lift of 20 feet the capacity would be a little less than one-half of this amount. That is to say

10 inches of water can be given to 24.5 acres of ground during 100 days where the lift is 10 feet and 12.25 acres where the lift is 20 feet; and 20 inches of water could be given to one-half of these areas respectively.

There were, during the year, 5,239 hours when the velocity of the wind equalled or exceeded a mean of 9 miles per hour and there were 3,531 hours when the mean velocity did not reach 9 miles per hour, during which time there was no water pumped or but very little, because the wind was too light. It is true, as the table of hourly records show, that some water was pumped during hours when the wind records show a velocity of less than 9 miles, but it is my judgment that these are cases when for a few moments the wind did have a velocity exceeding perhaps even 9 miles per hour but it did not last long enough for the instrument to register a mean of so high a velocity as that.

The mill did work on an average for the whole year 14.32 hours per day. From March 6 to Sept. 1 the average day's work was 10.74 hours, and this is the irrigation season.

The largest number of consecutive hours when no work was done was 168 or just one week during the last of July and the first of August.

THE INDICATED HORSE POWER DEVELOPED BY THE WINDMILL.

The determination of the actual horse power developed by this mill is not very readily nor very accurately deduced from the amount of water which has been pumped because of the extremely variable rates at which the pumps have been worked and because the mill has worked some of the time the Seaman, some of the time the 14-inch reciprocating pump and some of the time the two pumps together. Under these conditions the effectiveness of the pumps cannot accurately be determined.

To secure an approximate estimate of the work the windmill was able to do under different wind velocities 26 brake tests were made with the apparatus represented in Fig. 27.

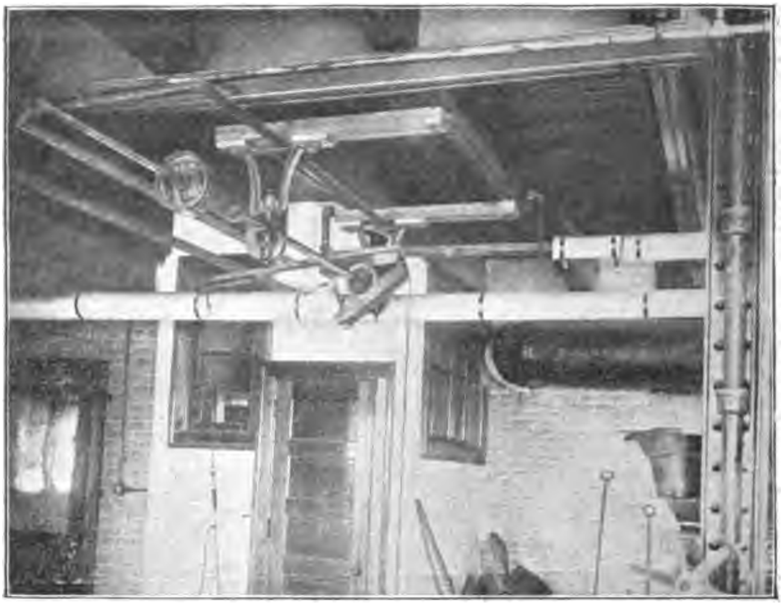

FIG. 27.—Showing the brake attached to pulley having a circumference of 2 feet and provided with flanges for holding water. The arm of the brake had a length to give a circumference of 20 feet. The tension on the arm was measured by a spring balance reading to ¼ lb and shown in the lower part of the cut to the left.

A part of these measurements were made upon the counter shaft and a part upon the vertical shaft of the mill, but on account of the difficulty of getting wind velocities of equal value and steadiness even in consecutive half hours it was not possible with the time at command to show an appreciable absorption of power in the transfer to the counter shaft and all of the results are tabulated together, as shown below:

Wind velocity, miles per hour.	Indicated H. P.	AVERAGE.		Barometer.	Temp. of air.
		Miles.	H. P.		
8.4	.2715	8.4	.2715	29.40	.0
12.	.5791	12.33	.5858	29.36	.5
12.4	.7230			29.36	.5
12.6	.4553			29.36	.25
13.2	.6213	13.2	.6213	29.40	.5
14.6	.7343	14.68	.8602	29.36	—.5
14.64	.9449			29.40	.5
14.8	.9016			29.40	1.
18.6	2.054	18.7	1.873	28.86	9.
18.8	1.692			29.40	1.
21.2	2.593	21.55	3.033	29.40	1.5
21.6	3.715			29.06	—2.
21.6	3.227			28.86	7.
21.8	2.597			.....	....
22.0	4.326	22.06	3.652	29.09	1
22.0	4.236			29.04	—2
22.2	2 394			.....	....
23.0	3.842	23.0	3 9965	29.07	—1
23.0	4.151			29 05	—1
24.0	5.983	24.3	4.7685	28.75	6.75
24.6	3.551			29.09	1.5
25.2	4.882	25.2	4.882	29 09	1.5
27.33	4.092	27.16	4.471	28.66	6.25
27.00	4.85			29.10	1.5
39.00	5.953	39.00	5.953	28.69	6.5
40.	5.971	40.	5 971	28.69	6.25

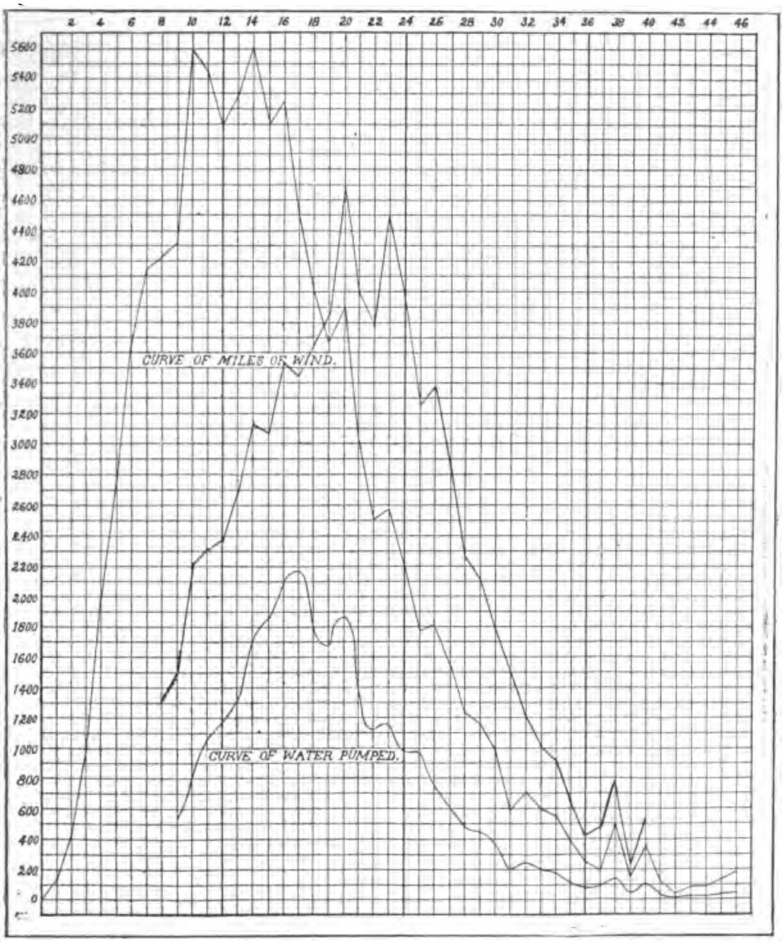

FIG. 28.—Showing in the upper curve, the number of hours of wind during the year, expressed by the numbers at the left, of the different velocities in miles per hour, expressed by the numbers at the top. The lower curve shows the number of tanks of water pumped with each wind velocity during the year, while the middle curve represents the number of horsepower-hours developed by each wind velocity as computed from the brake test.

Using the mean values given in the third and fourth columns in the last table a curve was plotted, and from this curve the indicated horse power for each wind velocity from 8 miles up to 40 miles per hour has been read off and introduced into the table which follows, where the indicated horse power has been multiplied by the number of hours of each wind velocity for the full year, thus securing the number of indicated horse-power-hours which are given in the fourth column of the table.

It will be seen from this table that the full year gives 7693.1 horse-power hours which is equal to 2.107 H. P. for 10 hours per day, and .8789 H. P. for 24 hours per day.

Table showing the indicated horse-power of a 16-foot geared windmill during one year computed from brake tests.

Wind, miles per hours.	Indinated horse power.	No. of hours of wind.	Horse-power hours.	Wind, miles per hour.	Indicated horse power.	No. of hours of wind.	Horse-power hours.
8	.25	528	132.0	25	4.59	71	325.9
9	.32	480	153.6	26	4.82	70	337.4
10	.40	559	223.6	27	4.99	57	284.4
11	.47	495	232.7	28	5.14	44	226.2
12	.56	425	238 0	29	5.28	40	211.2
13	.66	406	268.0	30	5.40	33	178.2
14	.78	401	312.8	31	5.52	19	104.9
15	.90	341	306.9	32	5.61	22	123.4
16	1.08	328	354.2	33	5.70	18	102.6
17	1.31	264	345 8	34	5.76	16	92.2
18	1.62	223	361.3	35	5.82	11	64.0
19	1.99	193	384.1	36	5.87	7	41.1
20	2.39	195	467.1	37	5.92	8	47.4
21	2.76	144	397.4	38	5.95	13	77.4
22	3.31	114	377.3	39	5.96	4	23.8
23	4.00	112	448.0	40	5.97	9	53 7
24	4.31	92	396.5				

THE WORK OF THE WINDMILL COMPARED WITH THAT OF A 2½ H. P. GAS ENGINE.

Pumping and brake tests have been made with a 2½ H. P. gas engine for purposes of comparison with the windmill, and the following results were secured:

The engine was set at work with two pumps with which the windmill has done nearly all of its service and the rate of pumping found to be such that in 365 days of 10 hours each the water lifted would be

$$41.68 \times 60 \times 365 \times 10 = 9{,}127{,}920 \text{ cu. ft.}$$

and this is

$$\frac{9{,}127{,}920}{3{,}449{,}939} = 2.35 \text{ times}$$

that pumped by the windmill

After the rate of pumping with this engine had been measured the pumps were thrown off and without stopping the engine or altering the gas supply the brake was applied to the counter shaft from which the pumps were driven and tightened until the speed of the shaft as recorded by a counter was the same as it had been during the pumping trial, and under these conditions the indicated horse-power was 1.8 while the effective horse-power was 1.02.

During a 6-hours' run with this engine there were lifted to a height of 12.85 feet 13,202.2 cu. ft. of water with a consumption of 458 cu. ft. of gas, costing $1.25 per thousand. This is a cost for fuel of 95.4 cents per day of 10 hours' work.

WORK DONE BY THE WINDMILL IN GRINDING CORN.

Several measurements of the rate of grinding corn with this windmill under different wind velocities have been made during the year.

The grinder used is the one sent out by the Aermotor Company, as being specially adapted to service with a windmill as a source of power. The grinder was driven from the same counter shaft which drives the pumps and its location in the laboratory can be seen near the center of the foreground of Fig. 24.

The corn used was a well dried variety of yellow dent and the mill was set so as to give a grade of meal represented in Fig. 29. A sample of the meal ground was sorted with a set of screens and the parts in 100 of each grade determined by weighing as given below and shown natural size in Fig. 29.

Too coarse to pass screen No. 8	3.3 per cent.
Passing No. 8 but retained by No. 10	3.4 per cent.
Passing No. 10 but retained by No. 16	24.3 per cent.
Passing through No. 16	69.0 per cent.

Seven of these grinding trials were made, each of them long enough to grind 100 lbs. of corn and the results obtained are given in the table which follows:

With the wind 8.25 miles per hour the corn ground was 15.1 lbs. per hour.
With the wind 11.5 miles per hour the corn ground was 107.16 lbs. per hour.
With the wind 13.398 miles per hour the corn ground was 156 lbs. per hour.
With the wind 18.18 miles per hour the corn ground was 195.4 lbs. per hour.
With the wind 23.6 miles per hour the corn ground was 389.2 lbs. per hour.
With the wind 25 miles per hour the corn ground was 431.1 lbs. per hour.
With the wind 34.8 miles per hour the corn ground was 993.2 lbs. per hour.

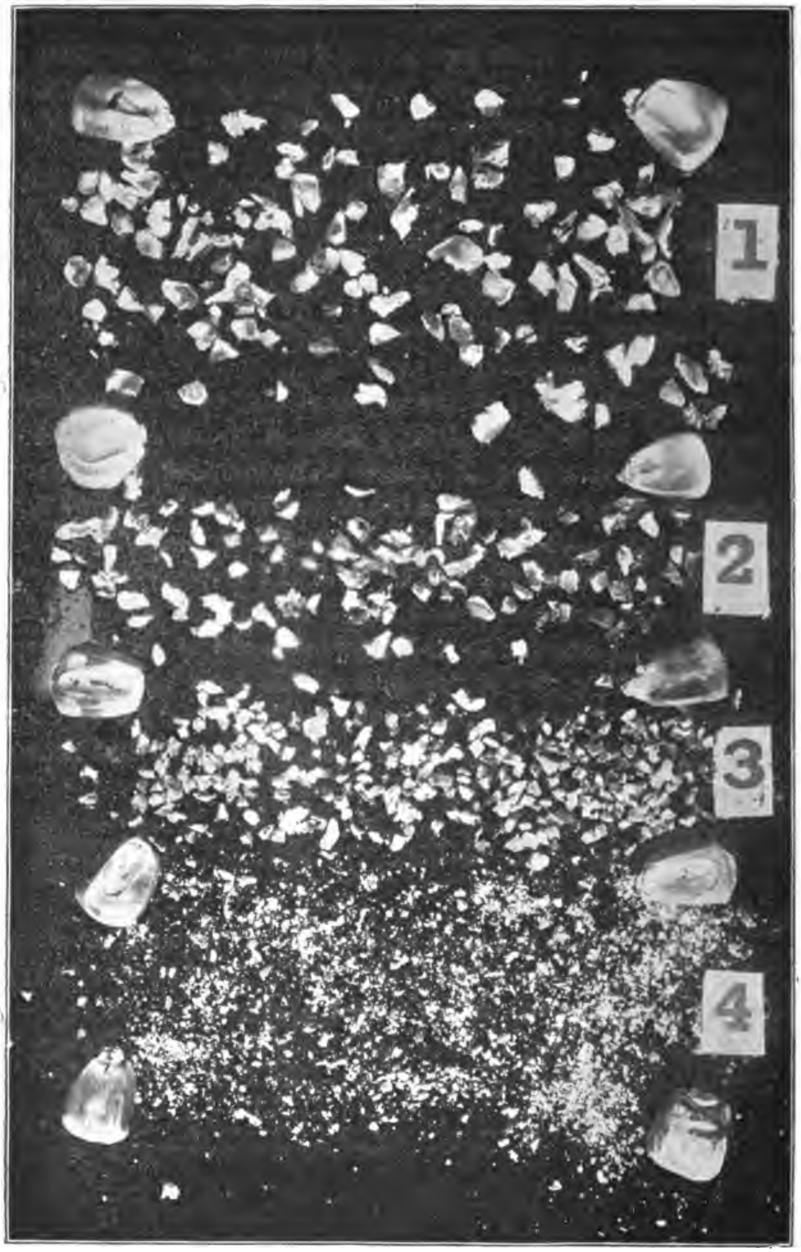

FIG. 29.—Showing the character of the meal ground during the grinding test. The meal is shown natural size. No. 1 grade made up 3.3 per cent.; No. 2, 3.4 per cent.; No. 3, 24.3 per cent. and No. 4, 69 per cent. of the meal ground.

Table showing the amount of corn which could have been ground during the year with all winds from 9 miles to 30 miles per hour.

Wind, miles per hour.	No. of hours of wind.	Amount ground per hr.	Total meal ground in the year.	Wind, miles per hour.	No. of hours of wind.	Amount ground per hr.	Total meal ground in the year.
9	480	15	7,200	20	195	262	51,090
10	559	48	26,830	21	144	298	42,910
11	495	87	43,065	22	114	333	37,960
12	425	117	49,725	23	112	371	41,550
13	406	147	59,680	24	92	400	36,800
14	401	161	64,560	25	71	431	30,600
15	341	169	57,630	26	70	468	32,760
16	328	177	58,055	27	57	503	28,670
17	264	186	49,100	28	44	538	23,670
18	223	193	43,040	29	40	573	22,920
19	193	226	43,620	30	33	608	20,065

This table makes the total amount of feed which could be ground by the mill in a year, 871,500 lbs., or 15,560 bushels of 56 lbs.

Grinding trials were also made with a Webster 2½ H. P. gas engine, and its rate was found to be 6,408 lbs. per day of 10 hours with a cost of fuel of 99 cents. The windmill was therefore able to do during the year the equivalent of 136 days of the 2.5 H. P. engine.

AMOUNT OF POWER LOST IN THE OFFSET PULLEYS.

We have already called attention to the fact that the windmill has been forced to work at a disadvantage on account of the offset in the shaft and have stated that on account of the unsteady character of the wind we were not able to measure what this loss is through brake tests. We did, however measure the force necessary to turn (1) the whole system of shafting without any load; (2) that part of the shafting below the offset pulleys; and (3) that part of the shafting above the offset and just below the windmill. These measurements were made by winding a ⅛ inch cord about the upper pulleys, carrying it through a small moveable pulley upon the hook of a spring balance and then over another pulley so as to change the horizontal pull to a vertical one. Weights were loaded upon the cord until sufficient pull was secured to make the shaft revolve continuously and nearly uniformly at a slow speed and the following results were secured:

For the whole system of shafting with belt on offset pulleys, the pull was....	13.85 lbs.
For the shafting below the offset pulleys with the belt off, the pull was......	6.30 lbs.
For the part of the shafting above the offset pulleys with belt off, the pull was	4.30 lbs.
This makes the pull on the whole shaft with the offset belt off	10.60 lbs.
And the loss in the offset belt	3.25 lbs.

As the diameter of the two offset pulleys is 14 inches, a steady pull of 3.25 lbs., when the shaft is making 500 revolutions per min., represents a loss in horse power amounting to .18; while the loss through the whole system of shafting, including the offset pulleys, would be for the same number of revolution per minute

$$\frac{13.85 \times .18}{3.25} = .767 \text{ H. P.}$$

With the shaft making 250 revolutions per min. the energy lost in the offset belt and pulleys would be .09 H. P., and in the whole system, not including loss in belts to pumps and grinder, it would be .384 H. P.

If these values are taken as representing the loss of power in transferring the energy developed by the wind to the laboratory we may make a correction for this loss and show what horse power was transmitted to the vertical shaft of the windmill just below the wheel and also what was lost by the transfer necessitated by the offset belt and pulleys. When this is done it will be seen that the offset pulleys decreased the efficiency of the windmill from .0445 H. P. at a wind velocity of 8.4 miles to .1459 H. P. at a wind velocity of 40 miles per hour. If we express these losses percentagely we get for the 8.4 mile wind a loss of 14.08 per cent., for a 14.68 mile wind a loss of 6.12 per cent.; for the 21.55 mile wind 2.79 per cent.; and for the 40 mile wind a loss of 2.39 per cent.

SUGAR BEET CULTURE IN WISCONSIN DURING 1897.*

F. W. WOLL.

During the past few years the interest in the question of sugar production from American beets has been steadily increasing in this as in other states in the Union. There has been considerable agitation as to the location of sugar factories in a number of localities in our state, and several local beet sugar associations were formed during the past year or two, for the purpose of ascertaining the adaptability of their particular locality to sugar beets, and to secure, if possible, the location of sugar factories in their midst. In order that we might be placed in a position to judge definitely as to the adaptability of the various parts of the state to sugar beet culture it was decided to resume work in this line at our Station during the past season.† The work outlined included three distinct phases:

First, it was intended to secure a large number of samples of sugar beets grown by farmers located in counties in which agriculture is an important industry or is likely to develop into such a one.

Second, one or more sub-stations were established in a number of agricultural counties, at which half an acre of sugar beets were grown under the direction of the writer, and an account kept of the labor and cost of cultivation; samples of the beets grown at these sub-stations were analyzed twice in the fall.

Third, variety tests of sugar beet seed from various sources were conducted at our Experiment Station farm, and also a fertilizer experiment with sugar beets on marsh soils.

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* Condensed from Bulletin No. 64 of this Station.

† For previous work in sugar beet culture in Wisconsin, see Bulletins Nos. 26, 30 and 55 of this Station; also our 8th and 9th Annual Reports.

A—ANALYSIS OF BEETS GROWN BY FARMERS IN DIFFERENT PARTS OF THE STATE.

Through the courtesy of U. S. Secretary of Agriculture, Hon. James Wilson, half a ton of sugar beet seed was donated to the Station for the purpose of conducting this investigation; other seed was bought by the Station of the Menomonee Falls Beet Sugar Co., or imported directly from Germany and France. The legislature of 1897 passed a bill appropriating $500 for defraying the expense of distributing the seed to Wisconsin farmers, and directed that each member of the Senate and Assembly be allowed 100 seed packages for distribution in his district. The members, with but a few exceptions, either furnished lists of names of constituents to whom they wished their allotment of seed sent, or personally took charge of the distribution of the seed in their district. The seed was sent out during the latter half of April and the beginning of May, the number of packages distributed being in all 13,766; of this number all but about 500 were distributed through members of the legislature.

In each package was inclosed the special bulletin of the Station, dated May 1st, 1897, giving directions for growing, harvesting and sampling sugar beets, with a shipping tag for forwarding the sample of beets grown from the seed sent, to this Station for analysis, and a description blank asking for information concerning the details of the work done in growing the crop, character of the soil, yield, previous experience in sugar beet culture, etc. The blanks were to be returned with the beet samples in the fall.

The analysis samples of the beets grown from the seed distributed by the Station began to arrive during the latter part of September, and continued without interruption until the beginning of December. The railroads of the state, with great liberality, forwarded analysis samples of sugar beets grown by Wisconsin farmers free of charge to Madison, and with the exception of a small percentage of samples which either through misunderstanding or intentionally were forwarded by express, all samples of beets received for analysis came by railway freight. The delay in forwarding the samples in some cases caused the beets to wilt, and some of the beets received about December 1st froze in transit, but such samples were always marked, as weighed and analyzed, so as to guard against wrong conclusions.

Analytical work performed.—As a rule, four assistants were occupied with the writer in the analysis of the beets received during the period given, and a clerk was kept busy calculating and recording the results of the analyses, making thus six persons actively engaged during this time in the analytical work connected with this investigation. In all 2,227 analyses were made during the past season. Of these, 1,663 were samples of sugar beets grown by Wisconsin farmers from seed furnished by the Station and, in a few cases, by private parties; 93 samples were sent in from the sugar beet sub-stations, and the rest were samples of beets grown at the University farm. All polarizations of the beet juices or extracts were made by the writer, and represent toward 8,000 polariscope readings; at least three readings were taken for each sample.

In the great majority of cases the beet samples came accompanied by the description blank properly filled out; outside of three districts, viz., around Merrillan, Eau Claire and Green Bay, but very few samples were received without this blank. In the places mentioned the farmers were supplied with seed by a corporation or by private parties interested in the sugar beet culture in their locality. The farmers who did not forward descriptions of their analysis samples were in all cases afterwards supplied with a description blank and requested to return the same properly filled out. In this way many empty spaces in the records were filled. In some cases the shipping tag had been torn off the package when received at the Station, and we were thus unable to identify the samples. These samples were, however, also analyzed and are included in the summary of the analyses made.

Character of season.— The general characteristics of the season were as described in our Bulletin No. 64, pp. 10–11; the spring was cold and wet, and the summer, with the exception of the month of July, was very dry and unfavorable to crops. In the southern part of the state the rainfall for the months May to October hardly amounted to two-thirds of normal.

Kinds of seed.— Where there is no seed given, the beets were grown, with but few exceptions, from the Florimond Desprez seed furnished to farmers through members of the assembly. The figures given in the last column but one of the table refer to the kind of seed shown in the following statement:

I. Florimond Desprez seed bought from Wisconsin Beet Sugar Co., Menomonee Falls, Wis., and imported by them from France.

II. Kleinwanzleben, imported from Germany by Henry T. Oxnard of Nebraska (growers, Rabbethge & Geiscke, N. G.), and donated to the Station by Hon. James Wilson, United States Secretary of Agriculture, Washington, D. C. (Senate seed.)

III. Vilmorin White Improved.

IV. Vilmorin White Improved Kleinwanzleben.

V. Vilmorin White Very Rich French.

The last three varieties were direcfly imported by the Station from the growers, Vilmorin-Andrieux & Cie, Paris, France.

VI. Vilmorin seed from Utah Sugar Company, Lehi, Utah, distributed by Mr. W. H. Holmes of Waupaca, Wis.

VII. Floto's Improved Kleinwanzleben, distributed by Wernich Seed Co., Milwaukee, Wis.

VIII. Floto's Improved Kleinwanzleben, donated by the grower to the Station and distributed by us.

IX. Seed distributed by Northwestern Sugar Beet Seed Co., of Merrillan, Wis.

X. Agnew's Kleinwanzleben, grown by J. B. Agnew, Agnews, Cal.

XI. Hoerning's Improved Kleinwanzleben, donated by Edmund Starke, Grand Island, Neb.

XII. Demesmay sugar beet seed, grown by F. Demesmay, Cysoing, (Nord), France; donated by the grower.

XIII. U. S. Dept. of Agrl. seed.

XIV. "French sugar beet seed."

XV. "Vilmorin."

XVI. "Desprez."

XVII. "Kleinwanzleben."

XVIII. Rumfeau ? Russian beet seed.

Seed No. XIII was distributed directly from the U. S. Dept. of Agriculture; Nos. XIV–XVIII were bought from various seedsmen by the farmers themselves, under the names given.

Results of analyses.— The detailed analyses of the samples of sugar beets received at the Station during the past season, with averages for each county, were given on pp. 16–59 of our Bulletin No. 64, with information concerning time of planting, length of time between planting and harvesting, character of the soil, average weight of beets as analyzed, estimated yield per acre, whether manured or not, and kind of seed used. The yield of beets per acre was not always given on the blanks, and the average figures in the column with this heading are therefore obtained from a smaller number of data than in case of the averages for the weights and the analyses of the beets.

The average figures for each county, given in the table following, are the arithmetical means of all data in the respective columns except in case of the column headed *Estim. yield per acre*, where some figures were not included in the averages, having been calculated from the yield obtained from only a small strip of land, or being more or less rough guesses. The table also gives the results of the work done during the years 1890–'92, re-calculated from the original records, and a summary of all analyses made during the four years given.

The table includes the average analyses of 527 samples of beets during 1890–'92, and 1,663 during 1897, or a total of 2,190 samples. The average estimated yields of beets given in the preceding table were obtained, in 1890–'92 from 265 reports; in 1897 from 838 reports, and in 1890–'97, therefore, from 1,103 reports.

Sixty-eight of the counties of the state are represented in the analyses made during the past season; Brown county leads with 101 samples of beets, Kewaunee being second with 74 samples. Ten counties furnished fifty or more samples each. The highest average for the sugar in the juice was obtained for Oconto county, with 15.48 per cent. (purity co-efficient, 79.6 per cent.; 11 samples analyzed), followed by Door county, which gave 15.11 per cent. of sugar in the juice, purity 77.4 per cent., as the average of 15 samples.

Results of analyses of sugar beets grown on Wisconsin farms during 1890–'92 and 1897.—Averages by counties.

COUNTY.	1890-'92.				1897.				SUMMARY FOR FOUR YEARS.			
	No. of samples.	Sugar in juice.	Purity of juice.	Estim. yield per acre.	No. of samples.	Sugar in juice.	Purity of juice.	Estim. yield per acre.	No. of samples	Sugar in juice.	Purity of juice.	Estim. yield per acre.
		Pr ct.	Pr ct.	Tons.		Pr ct.	Pr ct.	Tons.		Pr ct.	Pr ct.	Tons.
Adams	3	11.99	76.1	9.3	6	13.67	75.5	10.2	9	13.11	75.9	9.8
Ashland	......	......	......	......	5	11.42	74.2	3.0	5	11.42	74.2	3.0
Barron	3	12.74	77.0	17.7	15	12.94	74.3	12.0	18	12.90	74.7	14.1
Bayfield	......	......	......	......	1	10.96	73.5	16.5	1	10.96	73.5	16.5
Brown	4	10.75	74.9	17.9	101	13.12	75.5	14.0	105	13.03	75.5	14.3
Buffalo	9	13.48	77.4	15.9	8	12.96	75.3	11.2	17	13.24	76.4	13.0
Burnett	......	......	......	......	2	12.92	75.0	18.0	2	12.92	75.0	18.0
Calumet	8	16.67	82.6	14.7	48	12.61	72.4	11.8	56	13.19	73.8	12.1
Chippewa	13	12.72	77.5	23.6	34	12.18	74.2	11.7	47	12.25	75.2	15.1
Clark	7	14.15	81.4	10.9	61	11.97	74.9	11.7	68	12.19	75.6	11.6
Columbia	19	12.28	74.7	15.5	30	12.68	71.8	13.4	49	12.53	72.9	14.2
Crawford	4	10.09	72.0	15.3	2	12.09	72.3	9.7	6	10.76	72.1	13.1
Dane	14	12.98	76.7	14.4	44	13.51	71.3	12.7	58	13.37	72.6	13.2
Dodge	13	11.77	76.2	20.7	47	12.86	71.9	12.5	60	12.62	73.0	13.8
Door	3	14.59	80.0	21.4	15	15.11	77.4	10.0	18	15.02	77.7	13.0
Douglas	......	......	......	......	8	13.92	78.8	16.7	8	13.92	78.8	16.7
Dunn	13	12.49	79.8	11.5	26	12.97	73.7	12.6	39	12.86	75.6	12.2
Eau Claire	10	11.70	76.0	14.0	63	10.70	73.8	11.0	73	10.84	74.1	11.5
Fond du Lac	10	12.13	74.1	11.0	38	12.04	71.2	16.6	48	12.07	71.7	15.1
Forest	1	9.64	72.5	6.0	1	11.31	70.2	15.0	2	10.47	71.3	10.5
Grant	9	10.24	69.3	13.2	26	12.21	71.2	13.0	35	11.74	70.5	13.0
Green	6	12.84	77.5	15.2	4	10.16	65.5	14.0	10	11.77	72.7	15.0
Green Lake	1	11.31	78.1	......	13	12.06	72.9	11.5	14	12.01	73.2	11.5
Iowa	7	11.32	74.9	27.8	1	10.40	70.2	12.0	8	11.20	74.3	22.5
Iron	......	......	......	......	1	9.96	64.7	15.5	1	9.96	64.7	15.5
Jackson	1	7.79	65.6	......	64	11.57	77.4	10.6	65	11.51	77.2	10.6
Jefferson	23	13.96	79.0	17.5	13	13.55	72.8	15.0	36	13.81	76.8	16.5
Juneau	6	13.04	76.0	25.3	9	12.34	72.9	6.2	15	12.63	74.1	13.2
Kenosha	1	12.71	78.1	21.8	13	14.31	74.2	15.0	14	14.19	74.5	15.7
Kewaunee	30	13.58	77.1	35.1	74	13.38	75.4	14.2	104	13.44	75.8	16.8
La Crosse	10	12.58	76.1	15.2	60	12.75	80.6	12.5	70	12.72	79.9	13.0
Lafayette	4	12.27	77.0	26.4	6	10.47	66.3	9.4	10	11.19	70.6	16.0
Langlade	1	12.91	81.4	24.1	15	11.51	70.8	11.0	16	11.59	72.1	12.0
Lincoln	3	17.43	85.9	13.1	7	13.09	75.9	4.5	10	14.39	78.9	10.9
Manitowoc	16	12.61	80.4	16.4	49	13.42	74.9	14.4	65	13.22	76.3	14.8
Marathon	9	12.67	76.5	16.1	44	11.99	72.3	12.4	53	12.10	73.0	12.9
Marinette	2	8.77	64.5	28.5	27	13.23	76.6	9.5	29	12.92	75.7	10.9
Marquette	......	......	......	......	15	13.19	77.7	8.0	15	13.19	77.7	8.0
Milwaukee	6	15.51	83.4	19.8	14	14.17	77.7	15.2	20	14.57	79.4	18.4
Monroe	16	12.32	76.2	12.3	24	12.36	73.1	11.4	40	12.34	74.3	11.8
Oconto	12	13.76	80.7	13.5	11	15.48	79.6	17.4	23	14.56	80.2	15.1
Oneida	......	......	......	......	4	13.78	75.5	......	4	13.78	75.5	......
Outagamie	14	11.48	75.2	23.6	63	13.06	75.4	15.0	77	12.77	75.3	16.6
Ozaukee	5	13.14	79.0	20.7	17	14.00	75.7	11.1	22	13.81	76.5	13.0
Pepin	5	14.71	79.1	11.9	4	11.82	73.7	23.5	9	13.43	76.6	17.7
Pierce	......	......	......	......	12	12.56	73.2	15.0	12	12.56	73.2	15.0
Polk	1	11.09	75.4	......	5	11.90	72.6	17.3	6	11.76	73.0	17.3
Portage	8	12.02	75.1	12.5	33	13.12	73.2	8.3	41	12.91	73.6	9.3
Price	......	......	......	......	7	10.43	67.2	11.0	7	10.43	67.2	11.0
Racine	4	14.27	80.6	10.5	17	13.75	75.3	14.3	21	13.85	76.3	13.9
Richland	9	11.34	79.6	12.9	15	10.61	68.7	15.3	24	10.88	72.8	14.4
Rock	17	12.96	76.7	11.4	36	13.97	73.5	15.1	53	13.64	74.5	14.0
St. Croix	8	12.55	74.7	19.9	18	12.11	72.2	13.3	26	12.24	73.0	15.3
Sauk	8	9.67	71.5	23.8	23	12.78	72.4	13.0	31	11.98	72.2	14.8
Sawyer	1	10.69	73.8	26.1	......	......	......	......	1	10.69	73.8	26.1
Shawano	7	12.53	76.3	16.9	28	13.35	75.0	8.2	35	13.19	75.3	10.4
Sheboygan	27	11.71	74.3	16.8	55	12.96	78.0	15.1	82	12.55	76.8	15.6
Taylor	15	13.61	78.9	8.8	10	10.87	70.6	13.6	25	12.52	75.5	11.0

***Results of analyses of sugar beets grown on Wisconsin farms during 1890–'92 and 1897.—Averages by counties.*—Continued.**

COUNTY.	1890-'92.				1897.				SUMMARY FOR FOUR YEARS.			
	No. of samples.	Sugar in juice.	Purity of juice.	Estim. yield per acre.	No. of samples.	Sugar in juice.	Purity of juice.	Estim. yield per acre.	No of samples.	Sugar in juice.	Purity of juice.	Estim. yield per acre.
		Pr ct.	Pr ct.	Tons.		Pr ct.	Pr ct.	Tons.		Pr ct.	Pr ct.	Tons.
Trempealeau	5	13.61	79.4	16.5	54	10.92	73.2	10.1	59	11.15	73.7	10.7
Vernon......	11	12.19	75.6	12.8	22	12.83	72.3	12.0	33	12.61	73.4	12.3
Vilas	......	....	......	......	2	12.57	74.5	......	2	12.57	74.5	......
Walworth ..	10	12.99	77.4	19.5	3	14.32	78.1	11.7	13	13.29	77.5	18.4
Washburn ..	1	12.0	76.6	10.5	4	13.35	77.9	9.5	5	13.08	77.6	9.7
Washington.	17	14.21	78.2	15.2	29	14.82	75.8	13.4	46	14.59	76.7	14.0
Waukesha ..	19	12.87	77.2	13.3	26	14.53	75.8	13.9	45	13.83	76.4	13.8
Waupaca ...	14	12.76	77.1	12.7	55	13.34	74.9	13.5	69	13.22	75.4	13.4
Waushara ..	3	12.95	76.3	25.4	16	12.06	72.8	14.7	19	12.20	73.3	17.6
Winnebago..	14	13.19	76.8	14.6	32	12.12	72.6	14.3	46	12.44	73.9	14.4
Wood	7	13.25	79.4	14.7	20	11.68	70.7	11.2	27	12.08	73.0	11.9
Unknown ...	......	....	......	.. ..	7	11.48	72.9	......	7	11.48	72.9	......
Averages..	**527**	**12.76**	**77.0**	**16.3**	**1,663**	**12.67**	**74.1**	**12.8**	**2,190**	**12.70**	**74.8**	**13.6**

The average sugar content of the juice of the beets came above 12 per cent. in case of forty-nine counties, above 13 per cent. in case of twenty-six counties, and above 14 per cent. in case of eight counties.

Adaptability of different parts of the state to sugar beet culture.— The preceding table indicates what an investigation continued through four growing seasons has revealed as to the adaptability of the soil in different parts of the state to the culture of this crop. In case of a few counties, especially the extreme northern ones, the number of analyses made is not sufficiently large to warrant our drawing definite conclusions as to the quality of beets there grown, but in the large majority of counties, the number of analyses is ample to be considered a true representation of what beets grown in the respective counties will show when raised by farmers who have no special knowledge of the requirements of the sugar beet as to culture, soil, etc.

The counties producing the richest beets are those lying E. and SE. of the Wisconsin river, and those in the northwestern corner of the state along the Mississippi and St. Croix rivers, from Buffalo county and north. The Lake Shore region is shown to be peculiarly well adapted to culture of the sugar beet; all counties with an average content of sugar in the juice above 14 per cent. in the past season's analyses, border on Lake Michigan, or are adjacent to counties bordering on this lake.

By reference to a geological map of Wisconsin,* we find a striking similarity between the sections showing an average sugar content above 13 per cent. and the geological formations in the state, in this respect that these sections are either in the limestone regions where the limestone rock is covered by glacial drift (i. e., the eastern half and the lower northwestern portion of the state) or in the so-called Keweenawan group (the extreme northwestern counties). On the other hand, the counties which give the lowest average analyses, with only a few exceptions, and these all grouped in the extreme northern part of the state, lie in the driftless area in the southwestern part of the state, extending south of Chippewa and Clark counties between the Mississippi and Wisconsin rivers, or in the sandstone region directly north of this driftless area. This similarity is too regular and marked to be a coincidence, and cannot mean but one thing, provided the data at hand are sufficiently numerous to show the true effect of cultural conditions, viz., that the sugar beet in order to reach its highest development requires soils rich in lime, and with us, preferably such as are produced by glacial drift overlying limestone formations, or produced by the decomposition of the Keweenawan or copper-bearing series (shale, conglomorate, porphyry, etc.) in the extreme northwest of the state.

Scientists who have made a special study of the subject of sugar beet culture agree in placing a soil rich in lime as one of the requirements of the sugar beet, and it would seem that the results of this investigation, as given in the preceding, in a striking manner corroborate this view. The most fertile parts of the state have soils rich in lime,† while the residuary soils of the driftless area, whether clayey or sandy, and the sandy soils of the sandstone region, are poor in lime. Since the soil in the southwestern part of our state is produced from decomposition of the underlying limestone rock, and the arable land is largely surrounded by bluffs composed of layers of limestone rock or limestone and sandstone, it might seem an absurdity to some that the soil should be poor in lime; such is, however, the case, according to our best authorities on this subject.*

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* See Atlas accompanying the Report of the Geological Survey of Wisconsin, plate No. I.

† See Thirteenth Report of this Station, p. 305.

We cannot here enter into any discussion of the origin and composition of soils, and their relation to agricultural production. The interested reader will find a somewhat detailed statement of this subject in Geology of Wisconsin; chapter V, Soils and Subsoils of Wisconsin, by Prof. T. C. Chamberlin,† a work published at state expense and found in most public libraries of the state. It is possible that good beets may be produced in the driftless area and the sandstone region of our state, by thorough liming (lime fertilizers: lime, land plaster, marl, ground lime rock, etc.), and there does not appear any reason why they should not be made to produce rich beets through application of general fertilizers, as well as lime. Experiments in this line have been conducted by the Station during the present season and will be reported later. Without special treatment, soils of the character mentioned cannot, however, according to our best present knowledge, produce beets which will compare favorably in richness with those grown in the eastern and northwestern part of our state.

While the general features of the question of the adaptability of different parts of our state to sugar beet culture are as stated in the preceding, there are many exceptions in single instances, owing to differences in the farming methods pursued by different farmers and in the character istics and state of fertility of different soils in the same region; this accounts for the fact that analyses above 13 per cent. of sugar in the juice are on record for the season of 1897 alone, from all but two of the counties represented (see table on p. 179), and in case of these two counties, single analyses showing 14.07 per cent. and 14.68 per cent. of sugar in the juice were obtained in 1891. Such exceptional analyses can have no economic importance, however, since sugar factories can only be a success in regions where the averages of a large number of analyses for several seasons will come above the factory limit of 12 per cent. sugar in the beet, with a purity of 80 per cent.

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* See Chamberlin and Salisbury, Preliminary Paper on the Driftless Area of the Upper Mississippi Valley, Bull. 52, U. S. Geol. Survey; Merrill, Rocks, Rock Weathering and Soils, pp. 258 and 302; Hilgard, Relation of Soils to Climate, Bull. 3, U. S. Weather Bureau.

† Vol. I, 1873-1879, pp. 678-88.

Yield of beets.— We notice that the average estimated yield of beets per acre obtained for the years 1890-'92 is 16.3 tons; in 1897, 12.8 tons, or on the average for the whole investigation, 13.6 tons. This must be considered a very satisfactory average yield and is doubtless somewhat higher than would be obtained if large areas were planted to beets. In the majority of cases, the farmers reporting their yield per acre grew only a fraction of an acre of beets, and only exceptionally was more than an acre grown by any one party; hence the beets could receive better care and the chances for a full stand would be better than where several acres of beets were grown. The average yield of sugar beets per acre in Germany in 1894-5 was 12.8 tons; the Lehi (Utah) factory in 1895 reported an average yield of 11.5 tons per acre; the Chino (Cal.), 11.0 tons. It is not likely that we in our state shall be able to materially exceed the average yield obtained by industrious German farmers, and certainly not until our farmers have had several years' experience in growing the crop.

Sugar contents of beets.— The table shows that the average per cents. of sugar in the juice for the years given were as follows: 1890-'92, 12.76 per cent.; 1897, 12.67 per cent., or an average of 12.70 per cent. for the years 1890-'97, the last figure being the mean of nearly 2,200 analyses. The usual minimum standard for beets adapted to factory purposes is 12 per cent. sugar in the beet. Since beets contain about 95 per cent. of juice, this will correspond to $\frac{12}{.95} = 12.63$ per cent. of sugar in the juice. Our average, therefore, exceeds this minimum figure by a small fraction of one per cent.

Purity of juice.— Since non-saccharine substances in the juice prevent or render difficult the crystallization of sugar from the beets, it is plain that a high purity in the juice is a most important factor in the manufacture of beet sugar. The average purity coefficients of the juice obtained in our analyses were as follows: 1890–'92, 77.0 per cent.; 1897, 74.1 per cent.; 1890–'97, 74.8 per cent. The cause of the lower purity during the past season is not apparent; it is very likely in part, at least, to be sought in the unfavorable weather conditions to which the greater portion of our state was subjected during nearly the whole of the growing period. The averages for any of the periods given do not quite come up to the required factory standard of purity of the juice, which is 80 per cent.

Relative value of beets of different purities.— The problem of the relative value to the sugar manufacturer of beets of different purities is one not easily solved, and concerning which there is a great diversity of opinion among expert sugar makers. The nearest approach to the correct expression of this relation may be found in the quantities of sugar available for sugar manufacture in the different cases. To illustrate, if a quantity of beets tests 12 per cent. of sugar, with a purity of 80 per cent., one hundred pounds of these beets will contain $12 \times .80 = 9.6$ pounds of pure crystallizable sugar, which might therefore, under ideal conditions, be recovered as first sugar and in low-grade products. In the same manner, 100 lbs. of 13 per cent. beets with a purity of 75 per cent., would furnish $13 \times .75 = 9.75$ lbs. available sugar; that is, slightly more than beets of the former quality. According to practical factory experience, 12 per cent. beets of 80 per cent. purity will give the same amount of sugar per ton of beets as 13 per cent. beets of 75 per cent. purity, viz., about 160 pounds, but the former kind of beets are preferable for the reason that the cost of extracting the sugar is increased in case of beets of a low purity. Some factories do not receive beets showing less than 80 per cent. purity; others receive them at a reduced scale of prices. At the Grand Island (Neb.) beet sugar factory the following schedule of prices is in force for beets testing below 12 per cent. of sugar and 80 per cent. purity, according to the printed contract which the Oxnard Beet Sugar Co. make with their patrons:

For beets containing not less than:	*Price per ton.*
12 per cent. sugar and a purity coefficient of 80	$4 00
14 per cent. sugar regardless of purity	4 00
13 per cent. sugar, purity not lower than 78	4 00
13 per cent. sugar, purity not lower than 76	3 75
12 per cent. sugar, purity not lower than 79	
13 per cent. sugar, purity not lower than 75	3 50
12 per cent. sugar, purity not lower than 78	
13 per cent. sugar, purity not lower than 74	3 25
12 per cent. sugar, purity not lower than 76	
11 per cent. sugar, purity not lower than 78	
13 per cent. sugar, purity not lower than 73	3 00
12 per cent. sugar, purity not lower than 74	
11 per cent. sugar, purity not lower than 75	
For all beets below 13 per cent. sugar, purity not lower than 73	2 50
For all beets below 12 per cent. sugar, purity not lower than 74	
For all beets below 11 per cent. sugar, purity not lower than 75	

No beets are received containing less than 10.5 per cent. of sugar and a purity-coefficient of 73, and it is distinctly specified that low-grade beets, as given, shall not be delivered at the factory (unless otherwise directed) until after all beets that reach the required standard of 12 per cent. sugar, with a purity co-efficient of 80, shall have been worked up.

While beets of purity below 80 per cent. therefore can be worked, it remains a fact that sugar cannot be successfully manufactured on a commercial scale from such beets alone, and no sugar manufacturer would venture to establish a factory in a locality where beets of at least 80 per cent. purity cannot be grown when proper care and attention is given to the culture of the beets. This must be the minimum standard aimed at, and by using first-class seed, thorough preparation of the seed bed, and good, constant cultivation through the growing season until the beet field is "laid by" in the fall, we have abundant evidence that this purity can be reached in most sections of our state where the land has not been reduced to a low state of fertility through poor methods of farming or is not naturally unproductive.

Maximum analyses of beets.—From the nature of the case, the analyses of sugar beets made in this investigation give minimum results, and the average analyses can therefore in no way be taken as a measure of what can be done in this line by our farmers. The possibilities of our Wisconsin soils for sugar beet culture is more truly measured by the maximum results obtained in analyzing beets from the various parts of the state, than is indicated by the average analyses given. In the following table the highest analyses made of beets grown in the different counties are brought together. The conditions under which the samples were grown will be seen by reference to the general tables, pp. 14-59 in Bull. 64. All analyses given in the following table are from samples received in good condition, samples wilted or frozen when analyzed having for self-evident reasons been left out of consideration in this case.

Maximum analyses of sugar beets in each county, 1897.

County.	No. of analysis.	Av. wt. of beets.	Sugar in juice.	Purity of juice.	County.	No. of analysis.	Av. wt. of beets.	Sugar in juice.	Purity of juice.
		Lbs.	Per ct.	Per ct.			Lbs.	Per cent.	Per cent.
Adams	902	1.7	18.07	82.0	Milwaukee	1649	1.2	16.93	74.9
Ashland	540	2.2	13.11	75.1	Monroe	667	2.5	14.98	78.8
Barron	1838	1.7	16.44	81.5	Oconto	1742	1.8	18.93	81.4
Brown	2042	2.2	17.76	80.2	Oneida	1513	1.5	17.10	80.7
Buffalo	296	1.4	15.55	79.8	Outagamie	1869	2.2	17.27	82.9
Burnett	2123	2.9	14.04	78.8	Ozaukee	1521	1.0	17.68	82.6
Calumet	1544	1.4	16.40	82.2	Pepin	763	1.7	13.11	84.5
Chippewa	551	1.2	15.16	85.7	Pierce	1607	1.3	15.39	79.8
Clark	816	.7	15.88	82.9	Polk	1646	1.3	13.20	74.2
Columbia	1421	1.0	15.31	81.3	Portage	742	1.4	16.91	80.5
Crawford	1283	3.0	12.48	72.5	Price	843	.9	15.25	81.0
Dane	2010	1.0	17.17	83.6	Racine	1895	1.7	16.46	80.7
Dodge	1280	1.4	17.10	77.1	Richland	1429	1.7	13.88	76.5
Door	1460	1.2	16.31	85.7	Rock	2053	1.9	16.85	79.5
Douglas	1771	1.2	13.88	79.5	St. Croix	1153	1.1	15.77	84.8
Dunn	672	1.0	16.70	90.9	Sauk	1021	1.4	16.40	76.7
Eau Claire	1573	1.6	14.54	76.4	Shawano	1523	2.2	16.74	81.7
Fond du Lac	1452	1.4	16.60	79.7	Sheboygan	1510	1.7	18.75	85.1
Grant	1612	2.3	15.38	74.6	Taylor	1747	1.2	14.23	80.4
Green	1135	3.1	11.50	77.1	Trempealeau	1645	1.3	15.33	76.8
Green Lake	1315	1.5	14.59	77.5	Vernon	1424	1.3	16.91	77.9
Jackson	1772	1.5	16.18	86.0	Vilas	554	2.3	13.88	78.0
Jefferson	522	1.7	17.71	80.7	Walworth	1897	1.0	15.69	76.1
Juneau	694	1.4	16.19	81.2	Washburn	1515	1.5	15.88	81.9
Kenosha	431	1.0	17.33	71.5	Washington	1082	.8	18.02	76.4
Kewaunee	1827	2.1	17.56	83.4	Waukesha	1938	1.2	19.10	78.4
La Crosse	1018	2.1	16.67	82.6	Waupaca	1864	.5	17.79	81.9
La Fayette	446	2.0	15.64	77.5	Waushara	1142	1.3	14.97	81.5
Langlade	1196	1.1	16.17	79.3	Winnebago	1461	2.5	15.96	80.5
Lincoln	777	2.2	13.32	74.3	Wood	1534	1.7	16.03	79.5
Manitowoc	1795	1.5	16.59	85.1					
Marathon	1154	1.4	16.14	84.2	**Average for 64 counties**	......	1.57	15.97	80.1
Marinette	1710	1.4	16.81	82.4					
Marquette	1453	1.0	16.43	79.6					

Importance of proper culture of sugar beets.—The beet samples forwarded for analyses were largely grown by farmers who had no previous experience in sugar beet culture and who therefore often, through negligence or ignorance, failed to give the crop the attention which it requires. Only 124 farmers, or less than 8 per cent. of the total number, reported that they had grown sugar beets before. Novices in growing sugar beets rarely appreciate the importance of proper preparation of the land and of thorough cultivation. No crop can be more easily abused through neglect in these particulars than can the sugar beet. It is in an eminent degree an artificial product, having been gradually developed by means of selection and painstaking culture until to-day the best kinds of seed will produce beets containing three times as much sugar as was normally contained in sugar beets at the beginning of this century when the improvement of the beet root and the manufacture of beet sugar began. The sugar beet is therefore a thoroughbred of the most pronounced type. Under unfavorable conditions of soil or cultivation, or both, it will at once drop to where the crop was generations ago, so far as the sugar content is concerned. Many farmers do not understand or will not believe this until personal experience has proved to them the correctness of the statement. The sugar beet is more sensitive to abuse and makes greater demands to good culture and to fertility in the soil than any crop known to the writer. While, for instance, wheat or corn grown on poor land give a small yield, the quality of the crop being only somewhat poorer than when the cereal is raised on fertile land, the sugar beet under similar conditions not only gives a small yield, but the sugar content of the beet is at once depressed several per cent. and they may be less than half of what beets will test when grown on rich land from the same seed.

This is doubtless the explanation of many low analyses obtained in past years' work. Farmers in many districts in the state have been raising grain on their land for a generation or more, often without application of any kind of manure, until the land will not yield one-fourth of what was considered an ordinary crop when it was first brought under cultivation. Being unable to realize any profit from growing wheat or other cereals, many farmers in these districts now turn their attention to sugar beets, hoping to find in this crop a means of making farming pay. It cannot be stated too emphatically that sugar beets of good quality and purity cannot possibly be grown on land which has been robbed of their fertility through continuous grain-raising or other cropping, unless some of the fertility taken away year after year in the crops harvested be restored to the soil in the form of barnyard manure or artificial fertilizers- Sugar beets require soils in a good state of fertility in order to reach or exceed the factory standard of sugar content and purity, as well as to yield a fair acrerage. There is no remedy for worn-out land except manuring. Since artificial fertilizers are comparatively high-priced, their application cannot be recommended when small grains are raised, with the present low price of cereals, but for sugar beets the application of commercial fertilizers would doubtless prove a paying investment in case of worn-out soils which are otherwise suited to this crop. The European beet raiser would as soon think of growing a crop of beets without plowing and harrowing the land as without applying, directly or indirectly, some kind of artificial fertilizer or manure on it.

In the sections of our state where exclusive grain-raising has given way to diversified farming, dairying, stock raising or market gardening, the land is usually in a good state of fertility, and a sufficient amount of barnyard manure is produced every year so that no artificial fertilizers need be purchased. But where grain-raising is still continued as the sole reliance of the farmers, there is no hope for sugar beet culture until the system of farming is changed, and the manure produced by the stock kept is carefully saved and applied, or commercial fertilizers are purchased for the beet fields.

Influence of soil.—In order to trace the influence of the character of the soil on the sugar content of the beet, the analyses made during the past season have been grouped according to the different kinds of soil, and the average weight, sugar content, and purity of the beets grown on each kind of soil have been calculated. Under the group *garden soils* have been included all normal soils rich in humus, described as prairie, black, opening, pasture soils; in the same manner, *marsh soils* include such designated as swamp, tamarack, muck soils, etc. The other terms used are self-explanatory.

Summary of analyses, arranged according to character of soils; season 1897.

Character of soil.	No. of samples.	Weight of beets.	Sugar in the juice.	Purity.
			Per cent.	
Sandy	171	1.97 lbs.	12.98	76.0
Sandy loam	184	2.02 lbs.	13.16	76.5
Loam	129	2.28 lbs.	12.71	73.9
Clay loam	106	2.07 lbs.	12.96	75.0
Sandy clay	71	2.00 lbs.	12.86	74.9
Clay	265	2.11 lbs.	13.25	75.1
Garden	135	2.20 lbs.	13.20	74.4
"Bottom"	7	2.23 lbs.	11.64	70.6
Marsh	16	1.93 lbs.	12.46	75.2

We notice that the clay soils gave the richest beets, and humus soils (grouped under *Garden*) next, with sandy loam, sandy clay, sandy clay and loam, following closely one after the other in the order given, marsh and bottom land producing the poorest beets. The purity of the beets grown on sandy loam and sandy soils was higher than that of the beets grown on other kinds of soil; this is in the line of previous experience, since soils poor in organic matter have generally been found to produce beets low in non-saccharine matter, i. e., of a high purity. The cause of the lower sugar content of beets grown on light or medium soils must be sought in the fact that these soils have suffered more in our state from continuous cropping and are in a poorer condition of fertility than are the heavier classes of soils.

In order to further study the teachings of the analyses made during the past season concerning the relation between soil and product, the beet analyses below 10 per cent., and above 15 per cent. of sugar in the juice have been grouped according to the kinds of soil in which the beets were grown. The results of these calculations are given in the following table, in which are also included the maximum analyses for each county given on page 179, similarly grouped.

Per cent. of analyses below 10, and above 15 per cent. of sugar in the juice; also maximum analyses for each county, arranged according to character of soil.

Character of soil.	Total No. of analyses.	Below 10 per cent.		Above 15 per cent.		Max. analyses.		Per cent. of total No.			
		No.	Per cent.	No.	Per cent.	No.	Per cent.	Total No.	Below 10 pr.ct.	Ab've 15 pr ct.	Max. anal.
Sandy	183	12	6.6	15	8.2	15	8.2	15.3	9.8	9.8	25.0
Sandy loam	208	24	11.5	31	14.9	14	6.7	17.3	19.7	20.3	23.3
Loam	145	14	12.3	11	7.7	4	2.8	11.9	11.5	7.2	6.7
Clay loam	121	15	12.4	13	10.7	4	3.3	10.1	12.3	8.5	6.7
Sandy clay	75	4	5.3	8	10.7	2	2.7	6.3	3.3	5.2	3.3
Clay	301	36	12.0	61	16.9	17	5.6	25.1	29.4	33.3	28.3
Garden	149	14	9.4	21	14.1	4	2.7	12.4	11.5	13.7	6.7
Marsh	19	3	15.8	3	15.8	0	0.	1.6	2.5	2.0	0.
Total	1,199	122	10.2	153	12.8	60	5.0	100.0	100.0	100.0	100.0

The preceding results suggest that good beets can be grown in most kinds of soil, whether sandy, clayey or such fairly rich in humus, provided the beets are properly cared for. Thorough cultivation and fertility in the soil are factors of far greater importance in sugar beet culture than is the mechanical condition of the soil, or even to a certain extent its chemical composition. The ease of working the soil differs, of course, as much or more with this crop as with most other farm crops. The general rule may, however, be given in regard to soils for sugar beets, that medium light wheat- or potato soils, which can be worked to a depth of 14–18 inches and which will produce good yields of these crops, will be likely to prove well adapted to sugar beet culture. Such soils are easily worked and are readily penetrated by the beet root, which grows deep into the ground and is able to draw nourishment from the lower layers of soil that are not depleted of their supply of valuable fertilizing ingredients by other shallow-feeding crops, as may be the case with the top soil.

In the following tables the analyses made during 1897 have been grouped according to *a*, types of sugar beets, *b*, kind of seed, *c*, color of beets, *d*, kind of manure applied (if any), and *e*, preceding crop. The arrangement of the analyses in each case and the discussion of the average results obtained are given in our Bulletin 64, to which the reader is referred.

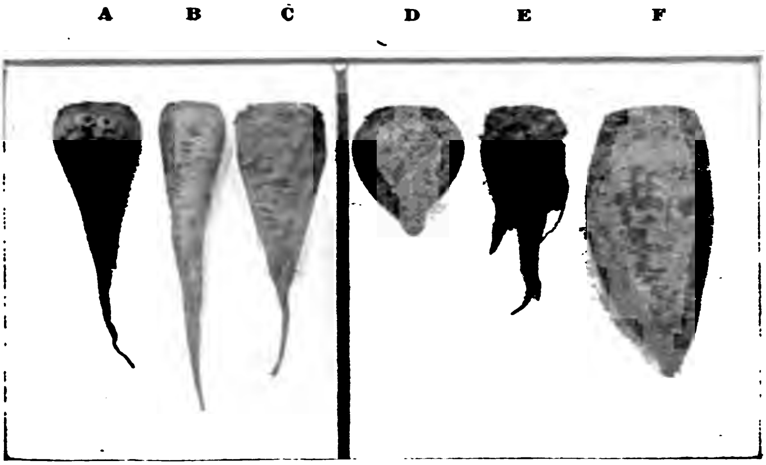

FIG. 30.—Types of sugar beets.

Relation of shape of beets to sugar content.

TYPES OF BEETS.	Total No of each type.	ANALYSES BELOW 10 PER CENT.		Average weight of beets.	Sugar in juice.	Purity of juice.	No of samples included.
		No.	Per cent.	Lbs.	Per cent.	Per cent.	
A	446	31	7.0	1.69	13.62	76.3	395
B	106	10	9.4	1.77	13.61	77.4	96
C	592	69	11.6	2.18	12.83	74.7	509
D	116	22	19.0	2.52	12.29	72.7	94
E	19	5	26.3	2.30	13.16	74.6	14
F	40	12	30.0	4.19	11.72	71.3	28
Total	1,319	149	11.3	....	....	....	....

Beets grown from different kinds of seed.

No. of seed.	Name of seed.	No. of Samples.	Av. weight of beets.	Sugar juice.	Purity coefficient.
			Lbs.	per cent.	per cent.
II	Kleinwanzleben, Neb	138	1.98	13.56	75.5
IV	Kleinwanzleben, Vilmorin	3	1.70	12.18	76.0
VIII	Kleinwanzleben, Floto	20	1.74	13.86	74.2
VII	Kleinwanzleben, Floto (Wernich)	7	2.53	13.05	76.8
X	Kleinwanzleben, Agnew	2	.90	13.72	82.5
XIII	Kleinwanzleben, U. S. Dept. of Agr	2	1.50	13.74	72.3
XVII	Kleinwanzleben, various sources	17	2.78	12.59	73.4
III	Vilmorin Improved	4	1.75	12.49	81.1
V	Vilmorin French	25	1.94	13.35	77.3
VI	Vilmorin, Utah	20	1.82	13.43	75.7
XV	Vilmorin, various sources	14	2.54	12.94	77.3
I	Desprez, Menomonee	7	1.86	12.65	72.8
XVII	Desprez, various sources	17	2.78	12.59	73.4
IX	Northwestern Beet Sugar Co. seed	15	1.41	13.27	78.4

White vs. red beets.

	Av. weight of beets.	Per ct. sugar in juice.	Purity coefficient.
	Lbs.		
White sugar beets (15 analyses)	2.19	12.49	74.1
Red sugar beets (15 analyses)	2.41	9.94	71.1
Red sugar beets (8 single analyses)	2.35	8.13	61.7

Influence of manure on quality of beets.

Manure.	No. of analyses.	Av. weight of beets.	Sugar in juice.	Purity of juice.
		Lbs.	Per cent.	Per cent.
Barn yard, well rotted	329	2.13	13.08	74.0
Barn yard, raw	30	2.11	12.56	73.0
Horse	111	2.14	13.00	74.1
Cow	86	2.34	12.79	72.7
Sheep	13	2.23	10.93	69.6
Hog	31	2.23	12.47	72.0
Hen	4	1.49	13.72	74.1
Wood ashes	5	2.09	12.88	73.2
No manure	310	2.02	13.02	74.7

Beets should not be grown on the same land several years in succession since they will then soon go down in yield and quality and will be apt to become a prey to insect and fungus attacks. German beet raisers advocate growing beets on the same land not oftener than every fourth or fifth year, three or four crops being raised between each crop of beets. For several reasons beets should follow a cereal crop. The regular four-year rotation adopted at the University farm is clover, corn, oats. This may be widened to a five-year rotation to include beets, as follows: Clover, corn, beet, oats, or may be changed to clover, corn, wheat or barley, beets. Where dairying or stock raising is practiced, this may well be widened into a six-year course with clover, pasture, wheat or barley, beets, oats,

Effect of preceding crop on quality of beets.

Preceding crop.	No. of samples.	Per ct. sugar in juice.	Purity coefficient.	Preceding crop.	No. of samplees.	Per ct. sugar in juice.	Purity coefficient.
Corn	193	12.62	74.6	Millet	8	13.08	74.9
Oats	73	13.25	76.5	Pasture	43	12.22	70.5
Barley	45	14.12	76.4	Potatoes	309	12.53	73.7
Wheat	30	12.86	75.5	Roots	94	13.27	73.4
Rye	22	12.48	75.2	Garden truck	162	12.40	73.2
Buckwheat	10	13.23	78.1	Tobacco	6	12.75	72.0
Peas	35	12.74	73.8	Small berries	9	13.12	72.9
Beans	25	12.46	73.7	Timber land	19	13.34	76.7
Clover hay	25	13.04	74.8	Summer fallow	4	14.45	80.1
Timothy or grass sod, hay	47	13.31	76.0	Total	1,159		

In Nebraska the best rotation, according to Myrick, is the five-year course: 1, beets, 2, wheat or oats, 3, corn, 4, wheat, oats or barley, 5, beets. If beets are wanted every four years, the Nebraska rotation is: beets, small grains, corn, beets. A good California rotation, according to the same author, is beets, wheat, barley, beets.

Local conditions, especially the particular system of farming followed as a main business, will usually determine the succession of crops most profitable in each case; hence farmers should study the subject of rotation of crops and adapt the general principles underlying the subject to their particular case, rather than follow any definite system which they may find advocated or which has given good results elsewhere.

B. WORK AT SUGAR BEET SUB-STATIONS.

The effort was made in the spring of 1897 to secure the co-operation of some farmer in each county of the state where agriculture is or is apt to become an important industry, for experiments with sugar beets, in which half an acre of beets was to be planted, and an account kept of the labor expended in growing the crop, and the yield obtained from the plot. Ten pounds of Kleinwanzleben, Neb., sugar beet seed (seed No. II, see p. 170), were sent on May 1 to twenty-six farmers who had expressed their willingness to undertake the work outlined, and during the following couple of weeks the same quantity of the same or other high-grade sugar beet seed was sent to twenty-one more farmers, making in all forty-seven proposed county sub-stations for sugar beet culture. Of this number forty farmers sent in forty-seven samples of beets taken in the latter part of September or in the beginning of October, and thirty-eight sent in forty-six samples taken at harvesting time. Thirty-three farmers returned the description blanks furnished, which were, with a few exceptions, well filled out. The remaining parties in some cases sent promises; in other cases no information was received as to the disposition made of the seed furnished or as to the conduct of the experiments outlined.

The main facts concerning the work done and the yield per acre obtained at the various sub-stations are given in the following table; the expense per acre of growing the beets has been calculated from the time-records furnished, at the following rates: One man, 10 cents per hour; man and horse, 15 cents per hour; man and team, 25 cents per hour.

Labor done and yields of beets obtained at county sub-stations.

Sub-stat'n.	County.	Name.	Post Office address.	Date of		Character of		Previous crop.	Size of plat, sq. ft.	No. times cultivated.	Time expended in growing crop, hrs			Expense per acre.	Yield per acre, lbs.	Previous experience.
				Planting.	Harvesting.	Soil.	Sub-soil.				Man.	Man and horse.	Man and team.			
1	Adams	W. B. Barnes	Easton	May 25	Nov. 5	Sandy	Clay	Potatoes	22,461	5	72	26	......	$21 32	16,000	None.
2	Barron	Dennis Rowan	Chetek	May 21	....	Clay loam	Sandy	Potatoes	21,780	3	......	......	......	......	22,000	
3	Barron	B. W. Utman	Cumberland	May 22	Oct. 21	Clay loam	Clay	Oats	21,780	4	75	13 5	......	19 05	26,000	Yes.
4	Brown	C. Radinz	Green Bay	May 5	Oct. 20	Black	Clay	Potatoes	21,780	3	120	35	......	43 50	34,000	
5	Calumet	A. A. Paulsen	New Holst'n	May 31	Oct 25	Sandy clay	Clay	Peas	22,687	2	28	23	60	40 80	24,000	Yes.
6	Chippewa	Jown W. Thomas.	Anson	May 15	Oct. 25	Sandy	Clay	Squash	11,434	3	101	12	......	45 33	......	None.
7	Clark	Geo. Heyndricks	Columbia	May 27	Oct. 7	Sandy loam	Clay	Potatoes	22,052	3	40	21	......	14 21	12,000	† Yes.
8	Clark	Peter Peterson	Curtiss	May 16	Oct. 18	Black clay	Clay	Corn	21,916	7	120	70	......	44 72	36,000	None.
9	Crawford	Geo. Schoeffer	Pr. du Chien	May 15	Oct. 20	Sandy clay	Clay	Corn	21,780	3	130	55	......	42 50	......	
10	Dodge	Thos. Wedemeyer	Richwood	May 13	Nov 2	Loam & clay	Clay	Maugels	22,869	2	66.5	4	35	27 47	32,000	Yes.
11	Door	D'minick Weiland	Sturge'n Bay	May 19	Oct. 20	Clay loam	Clay	Oats	21,780	8	26	10	......	8 20	21,000	None.
12	Green	Wm. Voegeli	Jordan	May 26	Oct 20	Black loam	Clay	Corn	21,780	4	144	34	......	39 00	33,000	
13	Iowa	Geo. E. Kelley	Mineral Pt.	May 24	Oct. 25	Clay loam	Clay	Turnips	21,502	....	......	......	......	......	......	Yes.
14	Jefferson	Julius Schoechert	Watertown	May 8	Oct. 28	Clay & sand	Clay	Clover	4,960	2	17	3 5	......	21 21	28,500	Yes.
15	Jefferson	Aug. Jaquith	Oak Hill	May 30	Oct. 20	Sandy loam	....	Potatoes	13,500	1	36	6	......	14 52	12,320	
16	Kenosha	G. H. Kröncke	Kenosha	May 15	Oct. 16	Black sand	Yellow sand.	Corn	10,890	3	32	32	......	32 00	56,000	Yes.
17	Kewaunee.	R. Ruhnke	Ahnapee	May 22	Oct. 23	Sandy loam	Gravel	Oats	21,780	3	46	21	......	15 50	12,000	None.
18	La Crosse.	W. I. Smith	West Salem	May 10	Oct. 25	Black clay	Clay	Potatoes	21,780	....	82	14.5	......	20 84	29,500	None.
19	Lafayette	Thos. Buxton	Leadmine	May 24	Nov. 20	Clay	Clay	Potatoes	13,068	3	......	......	......	......	......	None.
20	Milwa'kee.	C. T. Fisher	Wauwatosa	May 24	Oct. 28	Loam	Clay	Cuc'mbers	21,780	4	64	27	......	20 90	35,000	None.
21	Outagamie	H. M. Culbertson	Medina	May 11	Oct. 28	S'ndy cl. loam	Clay	Oats	10,890	4	82.5	3 7	5	40 20	28,000	Yes.
22	Racine	Adam Apple	North Cape	May 1	Oct 5	Sandy loam	Clay	Tobacco.	21,780	2	45	11	......	12 30	28,000	Yes.
23	St. Croix	P. J. Davin	Hammond	May 15	Oct. 18	Loamy clay	Clay & gravel	Po. & roots	22,052	6	142	34	......	38 12	47,900	
24	Sauk	W. T. Cass	Lone Rock	May 15	....	Sandy loam	Sand	Corn	10,890	3	......	......	......	......	......	
25	Sheboygan	Robert Vater, Sr	Plymouth	May 15	Oct. 22	Clay loam	Clay	Potatoes	42,879	3	130	110	......	29 97	35,200	None.
26	Vernon	Vern'n Co. Asylum	Viroqua	May 17	Oct. 5	Loam	Clay	....	11,200	3	242	......	......	*94 31	49,500	None.
27	Walworth.	G. A. Cowles	Whitewater	June 1	Oct. 27	Sandy loam	Clay	Hay	21,780	4	77	15	......	19 50	......	None.
28	Washi'gt'n	F. VanRhienen, Jr	So Germ'nt'n	May 17	Oct. 25	Black sand	Clay	Potatoes	23,040	2	90	22.7	......	23 44	33,500	Yes.
29	Waukesha	J. R. Watson	Sussex	June 3	Oct. 15	White clay	Clay	Barley	21,950	1	118	5	21	43 56	31,088	
30	Waukesha	A. L. Greengo	Colgate	....	....	Clay loam	Clay	Clover	34,650	....	257	13	12	43 89	28,752	
31	Waupaca.	Bartr'm & Holmes	Waupaca	May 17	Oct. 17	Sandy loam	Clay	Potatoes	21,780	3	45	59	......	26 60	33,600	None.
32	Waushara	J. G. Reinke	Pine River	May 22	Oct. 26	New, sandy	....	Rye turned under	21.780	2	90	12.5	......	21 75	17,000	
33	Winnebago	A. P. Shelton	Omro	May 20	Oct. 16	Black	Clay	Corn & b'ts	32,398	2	180	30	......	34 12	34,200	Yes.
		Average	......	......	......	......	......	......	......	......	......	......	......	$28 73	29,850	

* Not included in average.

† About two-thirds of the plat was drowned out by heavy rain; from sub-station 24 a similar experience was reported.

The expense per acre varies considerably according to local conditions: character of land, work of keeping the land free from weeds, working methods of the various farmers or their help, etc.; in the majority of cases the cost is from about twenty to forty dollars per acre, the average expense for twenty-eight sub-stations being $28.73. This does not include cost of seed, wear of machinery, or rent of the land, but all other items from plowing the ground to placing the beets in pit or cellar. Since an average yield of nearly 15 tons was obtained from an acre of land (mean of 27 reports), the expense was about $1.93 per acre. It is evident, however, that when grown on a larger scale than was the case in these experiments, the expense may be considerably reduced since more labor can then be done by machinery, and the work can in general be done more economically. According to the experience of practical beet growers, the total cost of growing a ton of beets when a good yield, say above 12 tons per acre is obtained, will not usually exceed $2.50 and may, under favorable conditions, be reduced to $1.50 per ton.*

The average yield per acre of beets obtained at the sub-stations, as reported by the farmers, was 29,850 lbs., ranging between twelve and fifty-six thousand pounds; the yields were generally estimated from the number of bushels or loads harvested from plats of one-quarter to one-half acre and was weighed only in exceptional cases. What has been said before in regard to the yield of beets obtained by Wisconsin farmers who forwarded analysis samples in this investigation, applies to this average estimated yield as well (see p. 176).

The results of the analyses of samples of sugar beets received from sub-stations are given in the following table.

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* A number of farmers who forwarded beet samples for analysis, furnished us with an account of their expenses in growing sugar beets. The following statement received from Wm. M. Godfrey, of Alma Center, is of particular interest on account of the large area planted to beets, viz.: 12 acres. The items given are as follows: Plowing, $19.25; harrowing, $7.88; rolling, $1.25; cultivating, $12.50; thinning and weeding, $104.00; hoeing, $20.50; harvesting, $125.00; total, $290.38, or $24.19 per acre.

COUNTY.	NAME OF GROWER.	POST OFFICE	FIRST SAMPLE.				SECOND SAMPLE.			
			Date of analysis.	Wgt. of beets	Sugar in juice.	Purity.	Date of analysiy.	Wgt. of beets	Sugar in juice.	Purity.
				Lbs.	Pr. ct.	Pr.ct.		Lbs.	Pr. ct.	Pr.ct.
Adams	W. B. Barnes .	Easton	....	......	....	......	Oct. 23	.82	14.79	82.5
Barron	Dennis Rowan	Chetek	Oct. 1	.87	13.20	82.8	....	......	....	......
	B. W. Utman .	Cumberland	Sept. 24	1.17	13.63	84.7	Nov. 1	1.80	15.38	86.9
Brown	Chas. Radinz.	Green Bay ..	Sept. 29	2.57	14.89	80.6	Oct. 19	2.40	10.31	69.3
Calumet ..	A. A. Paulsen.	NewHolste'n	Oct. 1	.83	14.79	82.5	Nov. 20	1.25	16.19	79.8
				.87	14.45	90.3	Dec. 2	1.08	*17.02	84.8
Chippewa.	J. W. Thomas.	Anson	Sept. 24	1.60	12.26	80.0	Oct. 25	1.70	13.43	87.2
Clark	Peter Peterson	Curtiss......	Sept. 24	2.20	11.70	81.5	Oct. 25	2.40	12.68	75.9
	G. Heyndricks	Columbia	Sept. 29	.98	13.45	88.4	Oct. 24	.90	18.14	88.8
			Sept. 30	.82	15.59	82.6	....	......	....	......
Crawford .	J. G. Schoeffer	Pr. du Chien	Sept. 17	1.55	11.83	82.7	Oct. 15	1.82	13.36	78.7
Dodge	T. Wedemeyer	Richwood...	Sept. 17	1.10	15.26	82.6	Nov. 11	1.60	14.66	79.7
Door	D. Wiland	Sturgeon B..	Oct. 4	1.82	15.35	75.4	Nov. 9	2.03	16.47	79.0
Dunn	CountyAsylum	Menomonie .	Sept. 23	1.32	12.20	83.0	....	......	....	......
Eau Claire	K. Rosholt....	Eau Claire..	Oct. 26	1.28	11.93	78.6	....	......	....	......
Green	W. Voogeli	Jordan	Oct. 5	.85	15.83	76.0	....	......	....	......
Iowa	Geo. E. Kelly .	Mineral Pt .	Sept. 17	.88	14.33	86.0	Dec. 6	.58	*19.20	79.9
				.28	15.18	85.3	....	......	....	......
Jackson ..	N. Merrill.....	Alma Center	Sept. 29	.87	10.64	81.7	Nov. 15	1.47	14.30	80.3
Jefferson..	J. Schoeckert.	Watertown .	Oct. 1	1.97	16.48	78.9	Nov. 9	1.15	16.72	79.4
								1.55	16.30	81.7
								1.90	15.73	77.1
	A. Jaquith....	Oak Hill....	Oct. 27	.52	....	......	Oct. 27	1.50	15.19	77.5
Kenosha ..	G. H. Kröncke	Kenosha.....	Sept. 30	1.18	9.13	71.2	Oct. 22	3.00	7.66	65.8
Kewaunee.	R. Ruhnke....	Ahnapee	Sept. 30	.68	16.63	89.5	Oct. 29	1.00	14.56	81.3
							Nov. 27	.93	†16.19	83.0
La Crosse	W. I. Smith...	West Salem.	Sept. 29	.82	16.63	87.5	Nov. 7	.92	12.75	74.0
La Fayette	Thos. Buxton.	Leadmine...	Sept. 30	1.07	11.50	77.1	Nov. 24	1.37	15.29	81.8
Manitowoc	J. Hall	Manitowoc..	Oct. 6	1.08	10.81	66.4	....	......	....	......
Milwaukee	C. T. Fisher..	Wauwatosa.	Oct. 1	1.45	14.73	81.4	Dec. 1	3.22	15.37	80.2
Outagamie	H. M.Culb'ts'n	Medina.	Sept. 30	.75	15.16	85.7	Nov. 10	1.28	16.61	83.2
				.60	15.44	82.0		.75	15.51	82.3
								.55	15.11	85.7
Ozaukee...	A. Selle........	Mequon	Oct. 1	1.77	13.49	79.3	Nov. 3	3.35	15.93	82.6
				1.50	10.18	71.7	....	......	....	......
Pepin......	J. Weisinger ..	Durand	Sept. 17	2.20	12.31	79.1	Oct. 25	2.87	15.03	86.1
Racine. ...	Adam Apple..	North Cape.	Sept. 24	3.50	13.24	73.5	Dec. 2	2.57	14.19	71.9
Rock......	O. N. Coon....	Fulton	Sept. 23	.57	11.80	76.4	Nov. 9	1.45	12.27	79.7
St. Croix..	P. J. Davin....	Hammond ..	Sept. 23	1.60	11.11	76.5	Nov. 11	2.57	14.52	83.9
Sauk	W. T. Cass....	Lone Rock..	Sept. 23	.88	12.19	83.9	Oct. 20	.48	13.55	83.1
	N. Darrow....	Reedsburg. .	Oct. 1	1.13	10.86	71.6	Nov. 29	2.70	*19.66	78.3
								2.30	*17.03	71.2
Sheboygan	R. Vater, Sr..	Plymouth...	Oct. 1	1.52	12.11	80.3	Nov. 1	2.62	15.16	80.5
Vernon....	Co. Ins. Asy...	Viroqua.....	Sept. 24	.83	17.22	86.7	Oct. 26	2.20	15.59	74.8
				1.10	15.43	82.8		2.00	15.33	74.0
Walworth.	G. A. Cowles..	Whitewater	Sept. 30	.43	13.54	82.8	Dec. 1	1.18	†14.28	76.3
Washi'gt'n	F. VanRhienen	S.Germant'n	Sept. 30	1.23	15.10	77.4	Nov. 5	2.60	16.28	80.7
Waukesha	A. L. Greengo.	Colgate	Sept. 30	1.42	11.15	77.0	Nov. 9	1.83	15.03	81.7
				1.37	12.76	82.8		1.47	17.19	88.1
				1.03	12.71	81.8		1.22	17.91	88.7
	J. R. Watson .	Sussex	Oct. 16	1.32	17.24	86.4	Dec. 1	1.92	17.14	80.4
Waushara.	J. Reinke	Pine River..	Sept. 30	.97	13.30	78.3	Oct. 28	1.82	16.24	83.3
Waupaca .	Bartram and Holmes......	Waupaca ...	Oct. 1	2.37	11.40	78.0	Oct. 26	1.17	16.27	85.4
Winneb'go	A. Shelton	Omro	Sept. 24	.73	14.06	80.0	Nov. 3	1.87	12.69	70.8
Average for 23 sub-stations in Southern half of state (30 and 31 samples, resp.)				**1.17**	**13.58**	**80.0**	....	**1.79**	**15.35**	**79.0**
Average for 13 sub-stations in Northern half of state (17 and 15 samples, resp.)				**1.42**	**13.35**	**81.7**	....	**1.59**	**14.97**	**82.5**
Average for 36 sub-stations (47 and 46 samples, resp.)				**1.26**	**13.49**	**80.6**	....	**1.72**	**15.22**	**80.2**

***Sample frozen. †Sample slightly wilted.**

The directions for taking the first sample were to measure off six feet in about the middle of two inside rows, not adjoining one another, having an even stand of beets and being of about average maturity; to dig all beets grown in this length, and to select three beets of average size for the analysis sample. The second sample was to be taken when the beets were harvested.

The table gives the analyses of 47 and 46 first and second samples, respectively.

FIG. 31.—View of Outagamie county sub-station.

By comparing the analyses made of the first and second set of beet samples for the different sub-stations it will be seen that the beets in general analyzed higher at harvesting than about one month earlier. In the last three lines of the table are given the average data for all counties, as well as those for counties in the southern and the northern half of the state separately. The latter division was made in order to ascertain whether any marked difference in the time of maturity of beets grown in these two sections could be traced; all counties lying south of the tier of counties from Trempealeau to Kewaunee Co. were included among the southern counties. The results show that the beets in the southern and the northern counties were at about the same stage of sugar content and purity when the first samples were taken; during the following month the average sugar content went up 1.77 and 1.64 per cent., in case of the southern and northern samples, respectively; the average purity of the second samples was slightly lower in the former and slightly higher in the latter case than was found in the corresponding first samples. The improvement in the sugar content was accompanied by an increase in the size of the beets, and this increase is more marked in case of the southern than the northern samples (.62 pounds against .17 pounds). While the crop in the majority of cases could be worked to advantage at the time of the first sampling, that is, during the latter part of September, the maximum yield of both beets and sugar per acre was not generally obtained until at ordinary harvesting time for roots with us, viz., during the latter part of the month of October.

The average per cent. of sugar in the juice for the second samples for all counties, as will be seen from the table, was 15.22 per cent., with a purity of 80.2 per cent. As the average yield of beets reported per acre was nearly 15 tons, we note that with good care and attention the beet crop will yield at the rate of 4,193 pounds, or over two tons of sugar per acre in our state, a standard which is not likely to be exceeded anywhere when beets from a large number of growers are included.

C. EXPERIMENTS AT THE UNIVERSITY FARM, SEASON 1897.

The experiments in sugar beet culture conducted at the Experiment Station farm during the past season come under three divisions: (1) variety tests with different kinds of sugar beet seed; (2) a similar experiment with choice imported or home-grown sugar beet seed, conducted under the direction of the Chemical Division of the U. S. Department of Agriculture; (3) a fertilizer experiment with sugar beets on marshy soil.

The following table of meteorological data for Madison, observations taken at Washburn observatory, May–November, 1897, is here presented:

Meteorological data for Madison, Wis.

May — Nov., 1897.

	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Total, May–Oct.
Mean temperature, ° F.	56.9	66.4	75.3	67.4	67.8	55.2	33.1	....
Normal mean temp	57.5	68.8	73.1	70.3	63.4	49.8	32.1	....
Mean max. temp	66.5	75.9	84.3	75.6	77.3	64.3	40.2	....
Mean min. temp........	47.3	56.9	66.3	59.2	58.4	46.1	26.0	....
No. of heat units*......	1,763.9	1,992.0	2,334.3	2,089.4	2,034.0	1,711.2	....	11922.8
Normal heat units	1,782.5	2,064.0	2,266.1	2,179.3	1,902.0	1,543.8	....	11731.1
Total precipitation, in.	.51	4.03	1.79	2.73	1.73	.86	1.83	11.65
Normal precipitation ..	3.60	4.15	2.56	2.61	2.82	1.10	1.35	16.84
Number of rainy days†.	8	12	9	10	5	5	8	....
Number of clear days ..	10	5	8	9	11	8	4	....

* Mean daily temperature multiplied by the number of days in the month.
† .01 in. or more precipitation.

The season was, in general, very unfavorable to sugar beet culture with us, being very cold and dry during May and beginning of June, and very dry and hot during the months of September and October. The temperature conditions during the latter months would have been favorable if the supply of moisture in the soil had not been reduced so that but little growth could be made. The number of clear and rainy days given for each month will give some idea of the amount of sunshine during the past growing season.

1. EXPERIMENTS ON MAIN FIELD.—The experiments made under the first two divisions given above were conducted on a three-acre field of the University Farm, the eastern half of which had been a meadow continuously since it came under cultivation, up to 1895, when rape was grown thereon; a crop of peas were raised on the land in 1896. The western half of the field was plowed once during the past twenty years, when it was planted to corn; it has been pastured during the last ten years until 1896, when it

was sown to rape which was pastured off with sheep. For a description of the work done in preparing the soil, and of the cultural conditions in general, see Bulletin No. 64, pp. 86-87. Fig. 32, gives a view of the main field, reproduced from a photograph taken on Aug. 11.

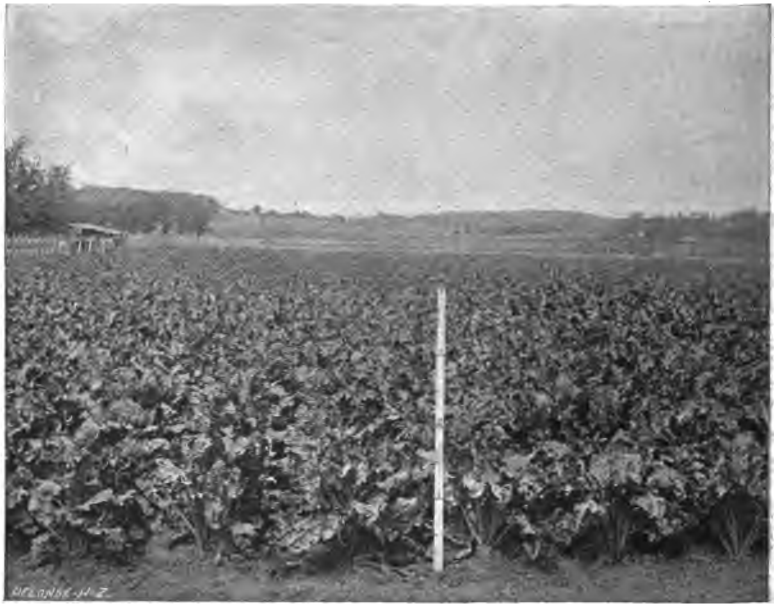

FIG. 32.—View of beets grown on Main Field.

The rows were run east and west, and were 560 feet long, of which 310 feet belonged to the eastern section of the field. Ten rows of each kind of seed were planted, except in case of Desprez, Men. seed (No. 1, p. 170), of which twelve rows were planted, the rows being 18 inches apart in this case, against 24 inches in case of all other varieties planted in the tests here reported. The kinds of seed planted were those given below in the order of the plats from south to north; some of these kinds were distributed for trial purposes to Wisconsin farmers, and hence are included in the list of seed, given on p. 170 of this report:

1. Kleinwanzleben, Neb. (seed No. II, p. 170). 2. Desprez, Men. (No. I). 3. Kleinwanzleben, Agnew (No. X). 4. Kleinwanzleben, Hoerning (No.

XI). 5. Vilmorin Improved (No. III). 6. Vilmorin Kleinwanzleben (No. IV). 7. Vilmorin French (No. V). 8. Desprez No. 2. 9. Desprez No. 2B (the latter two kinds of seed were forwarded for trial purposes by the growers, Florimond Desprez, Capelle par Trempleauve, Nord, France). 10. Wernich's Floto Kleinwanzleben (No. VII). 11. Kleinwanzleben, Floto (No. VIII). 12. Demesmay seed (No. XII, six rows only). 13. Kleinwanzleben, Neb. (2) (No. II, three rows only).

The beets were thinned and transplanted June 25-27 and the field was cultivated the last time on July 27. Harvesting was done October 13-19.

Sampling of beets.—The first samples of the beets grown in this field were taken on September 15, and the sampling was continued every tenth day from that day on until harvesting. Separate samples were taken of the beets on the eastern half and on the western half, sub-soiled and not sub-soiled plat. The results of the separate analyses are given in our Bulletin 64, the average results being given below.

Average results of sugar beet analyses, main field.

VARIETY.	EASTERN HALF.			WESTERN HALF.					
				Not sub-soiled.			*Sub-soiled.*		
	Wt. of beets.	Sugar in juice.	Purity.	Wt. of beets.	Sugar in juice.	Purity.	Wt. of beets.	Sugar in juice.	Purity.
	Lbs.	p. ct.	p. ct.	Lbs.	p. ct.	p. ct.	Lbs.	p. ct.	p. ct.
Kleinwanzleben, Neb..	.98	13.10	72.3	.65	15.03	76.9	1.40	14.95	78.6
Desprez, Men	.82	14.80	82.0	1.03	14.84	77.3	1.57	12.88	76.3
Kleinwanzleben, Agnew	.67	13.73	75.0	.60	14.15	76.6	.80	15 03	78.1
Kleinwanzleben, Hoerning..................	.93	15.06	77.2	.92	13.06	75.3	.93	15.26	80.0
Vilmorin Improved....	.82	14.83	78.9	.69	15.00	79.9	.99	14.50	79.0
Vilmorin Kleinwanzleben.................	.86	14.51	80.0	.71	13.60	84.9	1.04	14.04	82.9
Vilmorin French.......	.88	13.44	80.3	.71	14.65	79.1	.68	14.27	78.9
Kleinwanzleben, Floto*	.66	14.60	81.4	.57	14.41	77.4	.38	11.34	72.9
Desprez No. 2*.........	.64	15.29	80.2	.63	14.75	78.7	.59	10.52	70.4
Desprez No. 2B*........	.69	13.94	80.8	.53	13.12	76.3	.41	8.61	64.2
Wernich's Kleinwanzleben, Floto*..........	.56	16.86	82.4	.52	14.19	79.6	.33	9.92	67.0
Demesmay Improved*.	.61	14.64	80.1	.46	14.02	79.8	.24	9.04	66.8
Kleinwanzleben, Neb.2*	.52	16.27	81.2	.84	12.96	74.5	.29	8.99	64.4
Averages	.85	14.21	78.0	.76	14.33	78.6	1.06	11.42	78.8

* Not included in averages.

The data obtained at harvesting time are given in the following table. The per cent. of sugar in the beets has been calculated by use of the customary conversion factor .95. Owing to the failure of the crop in the northwestern quarter of the field, no separate account was kept of the yield of sub-soiled and not sub-soiled beets, but they were all harvested together.

The dry weather during the fall was exceptionally favorable to harvesting; the work of getting the beets out of the ground was light, and only a small percentage of dirt adhered to the beets. A bushel basket full of beets from each plat was weighed before and after washing; the per cent. of dirt thus found varied from 1.1 to 8.4 per cent. and was 3.4 per cent. on the average for eastern half, and 5.2 per cent. for western half.

Yield of beets and of sugar per acre, Main field.

No. of plat.	NAME OF SEED.	EASTERN HALF.				WESTERN HALF.			
		Yield of beets from plat.	Yield of beets per acre.	Sugar in the beet.	Sugar per acre.	Yield of beets from plat.	Yield of beets per acre.	Sugar in the beet.	Sugar per acre.
		Lbs.	Lbs.	Per ct.	Lbs.	Lbs.	Lbs.	Per ct.	Lbs.
1	Kleinwanzleben, Neb	3,422	24,040	12.72	3,059	2,874	25,030	15.80	3,959
2	Desprez, Men	2,826	22,060	11.71	2.543	3,122	30,230	13.71	4,144
3	Kleinwanzleben, Agnew	3,053	21,450	10 96	2,352	2,301	32,120	15.17	4,873
4	Kleinwanzleben, Hoerning	2,875	20,160	15 04	3.038	1,299	20,210	17.06	3,448
5	Vilmorin Improved	2,221	15,610	14.68	2,291	1,308	15,030	14.28	2,141
6	Vilmorin Kleinwanzleben	2,473	17,380	10 65	1,850	2,728	23,770	14.98	3,561
7	Vilmorin French	2,485	17,460	11 26	1,966	2,701	23,540	13.58	3,196
8	Kleinwanzleben, Floto*	2,258	15,860	14.24	2,259	1,472	12,820	14.05	1,801
9	Desprez White, No. 2*	2,081	14,620	10 95	1,602	1,429	12,460	14.38	1,790
10	Desprez White, No. 2 B*	2,108	14,810	15.05	2,228	1,408	12,270	11.71	1,436
11	Wernich's Kleinw., Floto*	2,111	14,840	15 65	2,320	1,236	10,760	13.62	1,467
12	Demesmay*	1,321	15,510	14.23	2.207	799	11,600	10.28	1,193
13	Kleinwanzleben, Neb. (2)*	887	20,760	15.83	3,287	855	10,300	10.75	1,058
	Total	30,121	....	....	....	23,032	....	....	....
	Average		18,043	13.22	2,385	....	18,472	14.18	2,620

* Not included in average for western half.

It will be noticed that the eastern half of the plat yielded at the rate of 9 tons per acre, and the western half at a somewhat higher rate. The calculated yield of sugar per acre was 2,385 and 2,620 lbs. for the eastern and the western half, respectively, the highest yields being obtained with Kleinwanzleben, Neb., in case of the western half (3,059 and 3,287 lbs.), and with Agnew's Kleinwanzleben, in case of the western, largely sub-soiled half (4,873 lbs.).

Cost of growing an acre of sugar beets.—A careful account was kept throughout the season of the labor done on the 3-acre beet field; valuing labor as previously given (see p. 187), we have the following summary:

Plowing and preparing the land	$12 42
Planting	1 70
Cultivating, hoeing, thinning and transplanting	51 63
Harvesting and placing in cellar	31 60
	$97 35

This sum, $97.35, or $32.45 per acre, is nearly four dollars higher than the corresponding figure obtained as the average for 28 sub-stations (see p. 188); the greater cost with us is easily accounted for by the weedy condition of the western half of the field, as well as by the fact that the harvesting of our beets was a comparatively slow and difficult job, since the different lots and varieties had to be harvested and kept separately.

II. EXPERIMENTS WITH HIGH-GRADE SUGAR BEET SEED.—These experiments were conducted under the auspices of the U. S. Dept. of Agriculture. Some of the kinds of seed sent were produced by the highest possible scientific culture from specially analyzed beets, which were stated to average 19 per cent. of sugar. According to the directions received, the government plat was surrounded on all sides by our regular beet field and was located in the southeastern quarter of our main field. The different kinds of seed received and planted by hand on May 22, were as follows:

Plat A.—Dippe Bros. Vilmorin Elite R I, from Dippe Bros., Quedlinburg, Germany.
Plat B.—1. Original Kleinwanzleben, grown by Kuhn, Naarden, Holland.
    2. Vilmorin Improved, grown at U. S. Sugar Beet Station at Schuyler, Neb.
    3 Demesmay sugar beet seed, grown by F Demesmay, Cysoing (Nord), France.
Plat C.—High-grade Commercial Kleinwanzleben.
Plat D.—High-grade Commercial Vilmorin's Improved "La Plus Riche."
White Improved Imperial Elite grown by Martin Grashoff, Quedlinburg, Germany.
Dippe Bros. Kleinwanzleben Elite W I, from Dippe Bros., Quedlinburg, Germany.

The plats were arranged in the following manner as suggested by Dr. H. W. Wiley, Chief Chemist of the U. S. Dept. of Agriculture: Plats A and B, each 21x24 ft., were placed in the middle and were surrounded by a border, C C, 67 feet long and 9½ ft. wide; the plats D_1 and D_2 were placed at the east and west ends of the C plat, being 21x40 ft. South and north of the whole plat, three rows were run, 110 ft. long, in which were planted the varieties given in the preceding statement, White Imperial being planted in the south three rows and Kleinwanzleben Elite in the north three rows. The rows were 18 inches apart; the effort was to have one good vigorous beet plant at about every nine inches in the row after thinning.

Main field. government plat.

DATE OF SAMPLING.	Per ct. root of whole plant.	Wt. of beets.	Analysis of juice.			Per ct. root of whole plant.	Wt. of beets.	Analysis of juice.		
			Sp. gr.	Sugar.	Purity.			Sp. gr.	Sugar.	Purity.
		lbs.		pr ct.	pr ct.		lbs.		pr ct.	pr ct.
	Imperial Elite.					*Dippe's Kleinwanzleben.*				
Sept. 20	70	.21	1.0755	14.44	79.1	64	.70	1 0695	14 57	86.3
Sept. 27	70	.40	1.0934	17.92	80.5	68	.90	1.0836	17 11	85.2
Oct. 11	78	.40	1.0834	17.04	85.0	71	.93	1 0917	18.17	83.0
Oct. 25	80	.58	1.0858	16.35	79.4	71	.50	1.1070	21.45	85.2
Nov. 5	......	.83	1.0740	14.35	80.1	......	.95	1.0812	16.42	84.0
Average	......	0.48	....	16.02	80.8	......	0.80	....	17 54	84.7
	Vilmorin La Plus Riche D_1.					*Vilmorin La Plus Riche D_2.*				
Sept. 20	73	.34	1.0882	16.96	80.4	67	1.03	1.0735	16.13	90.6
Sept. 27	73	.80	1.0923	17.58	79.9	72	1.15	1.0800	16.90	83.0
Oct. 11	72	.98	1.0895	17.93	83.8	73	1.23	1.0868	17.56	84.4
Oct. 25	82	.95	1.0860	16.40	79.5	78	1.35	1.0917	18.88	86.3
Nov. 5	......	1.20	1.0882	16.53	78.3	......	......	....	......	......
Average	......	0.85	....	17.08	80.4	......	1.19	....	17.37	86.1
	High-grade Kleinwanzl. C_1					*High-grade Kleinwanzl. C_2.*				
Sept. 20	73	.37	1.0825	16.45	83.0	72	1.05	1.0850	17.94	87.9
Sept. 27	70	.55	1.0898	17.21	80.0	65	.70	1.0842	16.70	82.6
Oct. 11	59	.50	1.0870	16.15	77.5	75	.70	1.0885	17.57	83.0
Oct. 25	78	.50	1.0810	14.35	73.6	82	1.30	1.0940	19.18	85.7
Nov. 5	......	1.13	1.0845	16.90	83.5	......	......	....	......	......
Average	......	0.61	....	16.21	79 5	......	0.94	....	17.85	84.8
	Vilmorin Impr., Neb., B.					*Demesmay Impr. B.*				
Sept. 20	70	.75	1.0725	15.06	85.7	76	.80	1.0655	13 23	82.8
Sept. 27	76	.45	1.0810	16 70	85 7	81	.93	1.0695	13 49	79.8
Oct. 11	80	1.13	1.0848	17.01	83.6	78	1.10	1.0678	12.85	77.9
Oct. 25	91	.75	1.0857	15.86	77.2	89	.85	1.0798	15.95	83.0
Nov. 5	......	.71	1.0800	15.71	81.5	......	.93	1.0690	13.66	81.4
Average	......	0.76	....	16.07	82.7	......	.92	....	13.84	81.0
	Orig. Kleinw. Holland B.					*Dippe Vilmorin A.*				
Sept. 20	68	.45	1.0860	16.63	80.7	63	.62	1 0790	16.05	84.3
Sept. 27	67	.20	1.0946	18.57	82.4	73	1.00	1.0852	16.86	82.5
Oct. 11	73	.40	1.0935	17.95	80.6	73	1.10	1.0895	17.49	81.7
Oct. 25	73	.30	1.0980	17.34	74.5	82	1.03	1.0920	18.34	83.6
Nov. 5	......	.35	1.09 0	18.65	81.8	......	.75	1.0827	16.91	85.1
Average	......	0.37	....	17.83	80.0	......	0.90	....	17.13	83.4

The germination of the seed planted in this experiment, as well as of that planted in our other trials was determined by Prof. Goff, and are given on pp. 300-301 of our

Fourteenth Annual Report. It will be seen that the germinative power of the different kinds of seed was very good, with the possible exception of the Schuyler, Neb., seed, which was old seed, and the Dippe Bros. Vilmorin Elite seed. The average germination of the seed was 167 per cent., ranging from 115 to 231 per cent., the latter result being obtained with the White Improved Imperial Elite.

The first samples of the beets raised on the government plat were taken September 20; another sample was taken September 27, and after that time every fourteen days, until the beets were harvested on November 5.

The results of the analyses are given in the preceding table. The C_1 samples were taken south of the A and B plats, and C_2 samples north of these plats. In the same manner, the D_1 and D_2 samples were taken from the plats east and west, respectively, of the central plats.

The per cent. of sugar in the juice but rarely exceeded 18 per cent. in case of the different varieties, the average figures ranging from 13.84 per cent. (Demesmay) to 17.85 per cent. (High-grade Com. Kleinwanzleben, C_2); the purity of the beet juice was good, viz., lowest 79.5 (High-grade Com. Kleinw., C_1), highest 86.1 (Vilmorin La Plus Riche, D_2).

The yield of beets from the plat, obtained at harvesting, November 5, and the calculated yield of beets and of sugar per acre are shown in the following table:

Yield of beets and of sugar, government plat.

NAME OF VARIETY.	YIELD OF BEETS.		Average weight of beets.	Sugar in the beet.	Sugar per acre.
	From plat.	Per acre.			
	Lbs.	Lbs.	Lbs.	Per cent.	Lbs.
Imperial Elite	272.3	21,210	.45	13.63	3,300
Vilmorin La Plus Riche	1,167.3	28,290	.64	15.70	4,441
High-grade Comm. Kleinwanzleben	1,170.0	30,660	.56	16.05	4,920
Dippe Bros. Kleinwanzleben Elite	311.7	34,380	.66	15.60	4,995
Dippe Bros. Vilmorin Elite	336 6	29,090	.58	16.06	4,672
Demesmay	234.4	31,520	.61	12.98	4,092
Vilmorin, Schuyler, Neb	76 7	30,940	.59	14.92	4,616
Org. Kleinwanzleben Holland	26.0	15,730	.27	17.72	2,788
Total	3.595.0				
Average	....	28,103	....	15.04	4,228

The average yield of beets per acre obtained was over 14 tons, or about 5 tons more than the yield obtained from either half of the main field. The average calculated yield of sugar per acre was 4.228 lbs., the lowest yield being obtained in case of Orig. Kleinwanzleben, Holland (2.788 lbs.), which variety plainly suffered most from the drouth, and the highest in case of Dippe's Kleinwanzleben Elite (4.995 lbs.).

III. FERTILIZER EXPERIMENTS WITH BEETS ON MARSHY SOIL.—The experiments described here were made for the purpose of ascertaining the system of fertilization best adapted for sugar beets grown on marsh soils. There is a general opinion that sugar beets cannot be grown to advantage on marsh soils, since the per cent. of sugar in beets grown on such land and the purity of the juice will generally be considerably depressed. The fact that a number of European sugar factories, so far as is known, to a large extent are supplied with beets grown on marshy soils with the very best results shows, however, that such soils with proper fertilization may be advantageously utilized for growing this crop.

The part of the University marsh on which the experiments were conducted was tile-drained in the fall of 1895 and grew a crop of corn during 1896. The soil is very porous and loose, and was extremely dry throughout the early part of the summer. A chemical analysis of the soil on the experimental plat, made by Mr. Vivian, gave the following results:

Chemical analysis of soil on marsh field.

Total insoluble matter	**70.31**	**per cent.**
Total volatile matter	**18.08**	**"**
Nitrogen	**.44**	**"**
Potash	**.30**	**"**
Phosphoric acid	**.28**	**"**
Lime	**1.63**	**"**

The plat was plowed on May 6 and prepared for planting on May 28. The fertilizers given below were mixed with moist soil from the respective plats before being scattered over the plats, and were then harrowed in. The nitrate of soda was added in two portions, at planting time and two weeks after thinning and transplanting, on July 12. The applications of fertilizers on the plats are shown below; the aim sought was to compare the effect of different kinds of potash and of phosphate fertilizers between themselves, and to note the effect of one-sided nitrogen-phosphoric acid, nitrogen-potash and potash-phosphoric acid fertilizers.

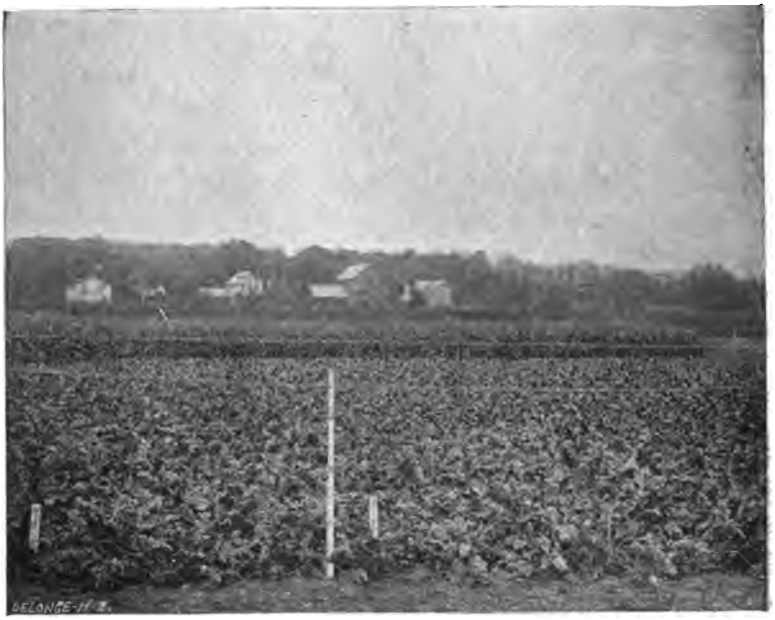

FIG. 33.—View of beets on Marsh Field.

The drought of the past season told more on this plat than on any other part of the University farm. The beet seed was slow in germinating, but after the rains of July the stand was good until the severe drought of August and September began to tell on the plants, and their growth was checked. The beets directly above the tile-drains made a more vigorous, healthy growth than any other part of the field; the course of the drains was, in fact, plainly seen at a distance from the plat, from the appearance of the beets along these lines. The beets grown on this plat were almost without an exception of the type B (see p. 184), being very thin and slender, the roots of some going over 2 feet into the ground in their search for water. In a season of copious rains it is possible that both the appearance of the beets and the relative yields obtained on the different plats would have been changed.

The seed used was Vilmorin French sugar beet seed (see p. 170.) At one end of the field a couple of rows were planted of seed left over from the government variety tests, viz., of Dippe Kleinwanzleben Elite, Dippe Vilmorin Elite and Imperial Elite. No fertilizers were applied on these rows, the object being to compare the quality of beets grown on this marsh soil with such grown in the main field, on clay loam. The total size of the experimental field was 200 ft. long by 75 ft. wide; the blank plats consisted of two rows, and the fertilized ones of four rows; the two middle ones of the latter were harvested and weighed separately, and the yield of beets per acre calculated on basis of the figures thus obtained. The kinds and amounts of fertilizers applied were as follows:

Plat 1.—No fertilizer.
Plat 2.—Nitrate of soda (10 lbs., equivalent to 360 lbs. per acre); basic slag (15 lbs., equivalent to 540 lbs. per acre).
Plat 3.—Nitrate of soda (10 lbs., 360 lbs.); kainit (20 lbs., 720 lbs.)
Plat 4.—No fertilizer.
Plat 5.—Muriate of potash (4 lbs., 144 lbs.); basic slag (15 lbs., 540 lbs.).
Plat 6.—No fertilizer.
Plat 7.—Muriate (4 lbs., 144 lbs.), bone superphosphate (10 lbs., 360 lbs.).
Plat 8.—Muriate (4 lbs., 144 lbs.) bone superphosphate (10 lbs., 360 lbs.), nitrate of soda (10 lbs., 360 lbs.).
Plat 9.—No fertilizer.
Plat 10.—Sulfate of potash (4 lbs. 144 lbs.), superphosphate (10 lbs., 360 lbs.), nitrate of soda (10 lbs., 360 lbs.).
Plat 11.—Sulfate (4 lbs., 144 lbs.), bone meal (10 lbs., 360 lbs.), nitrate of soda (10 lbs., 360 lbs.).
Plat 12.—No fertilizer.
Plat 13.—Carbonate of potash-magnesia (4 lbs., 144 lbs.), superphosphate (10 lbs., 360 lbs.), nitrate of soda (10 lbs, 360 lbs.).
Plat 14-17.—No fertilizer.

Average analyses of beets from marsh field, season 1897.

Plat No—Fertilizer used	Weight of beets	Sugur in juice	Purity of juice	Plat No.—Fertilizer used.	Weight of beets	Sugar in juice	Purity of juice
	lbs.	pr ct	pr ct		lbs.	pr ct	pr ct
1—No fertilizer	.71	13.64	79.1	9—No fertilizer	.68	15.23	80.2
2—Nitrate, odorl. phosphate	.71	13.89	83.4	10—Nitrate, sulfate, superphosphate	.72	13.54	76.4
3—Nitrate, kainit	.70	13.86	80.2	11—Nitrate, sulfate, bone meal	.64	14.93	78.0
4—No fertilizer	.83	13.29	85.4	12—No fertilizer	.58	14.75	78.8
5—Muriate, oderl. phosphate	.81	13.23	78.9	13—Nitrate, carb., superphosphate	.67	12.84	74.6
6—No fertilizer	.78	13.62	81.7	14—No fertilizer	.52	13.75	77.2
7—Muriate, superphosphate	.73	15.11	81.8	15—Dippe Kleinw. Elite	.60	15.43	79.7
8—Nitrate, muriate superphosphate	.73	13.99	80.2	16—Imperial Elite	.71	15.04	83.7
				17—Dippe Vilmorin Elite	1.07	14.24	79.5

The sampling of the beets began on September 20, and was continued every ten days after that date, until harvesting time. The average results of the analyses of beets from the different plats are shown in the preceding table:

Since the beets had not in all cases matured at the time of the first sampling, the average data obtained for the various plats can not give a correct idea of the comparative value of the fertilizers applied. This may, however, be found by comparing the data obtained at harvesting time, as shown in the following table. The last four columns of the table give the differences in quality and yield of the beets fertilized, as given above, and the corresponding blank plats (averages for plats 1 and 4 compared with that of plat 2 and of plat 3; average for 4 and 5 compared with that of plat 5, etc.).

Yield of beets and of sugar, marsh field.

Plat No.	Yield of Beets.		Sugar in the beet.	Yield of sugar per acre.	Increase or Decrease Over Control Plats.*			
	From plat.	Per acre.			Yield of beets per acre.	Sugar in the beet.	Purity coefficient.	Yield of sugar per acre.
	lbs.	lbs.	per ct.	lbs.	lbs.	per ct.		lbs.
1	231	16,780	13.78	2,314	....	....	....	....
2	200	14,520	12.43	1,804	—20	—1.43	—2 2	—210
3	232	16,850	12.12	2,041	2,310	—1.74	—3.9	27
4	169	12,300	13.93	1,714	....	....	....	....
5	175	12,700	13.56	1,721	1,400	1.32	1.3	321
6	142	10,300	10.54	1,086	....	....	....	....
7	160	11,610	13.11	1,523	845	1.05	2.7	211
8	173	12,560	12.60	1,582	1,795	.54	.1	270
9	155	11,230	13 68	1,537	....	....	....	....
10	156	11,320	12.49	1,415	225	—1.28	—5.4	—113
11	175	12,710	14.11	1,793	1,615	.34	—.9	265
12	151	10,960	13.86	1,519	....	....	....	....
13	159	11,540	13 97	1,888	1,559	.78	3 0	565
14	124	9,001	12.51	1,126	....	....	....	....
15	108	7,839	13.86	1,086	....	....	....	....
16	143	10,380	11.86	1,227	....	....	....	....
17	104	7,550	13.49	1,018	....	....	....	....
	Average	**11,774**	**13.11**	**1,553**	....	....	....	....

***—, decrease; other figures, increase.**

The yield of beets per acre on the plats was very small, viz., less than six tons for the whole field, and the average yield of sugar per acre was 1,553 lbs. The latter yield was increased over one-third by the application of a mixture of fertilizers consisting of double-carbonate of potash and magnesia, bone superphosphate and nitrate of soda, the plat receiving a dressing of muriate and basic slag giving second best results. The mixture of fertilizers which is generally applied in beet-growing districts in Europe, viz., nitrate of soda, sulfate of potash and bone superphosphate (plat 10) produced the poorest results, next to plat 2 which received only nitrate of soda and basic slag. It would not be safe to accept any of these results as conclusive, both on account of the abnormal character of the season and because they represent only one season's findings. The fact that the potash salts and the basic slag were not sown on the plats in the fall, as they should be, in order to produce best effects, also suggests the need of caution in interpreting the results.

Beets from main field and from marsh plats.—The influence of soil on the quality of sugar beets will be observed from the data compiled in the following table:

Sugar beets grown on main field and on unmanured marsh plats, 1897

NAME OF VARIETY.	MARSH FIELD.		MAIN FIELD.	
	Sugar.	Purity.	Sugar.	Purity.
	Per cent.	Per cent.	Per cent.	Per cent.
Vilmorin's French	13.74	75.9	13.44 14.65 14.27	80.3 79.1 78.9
Dippe Kleinw. Elite	15.43	79.7	17.54	84.7
Dippe Vilmorin Elite	14.24	79.5	17.13	83.4
Imperial Elite	15.04	83.7	16.02	80.8

Changes in beets toward and after maturity.—The data obtained in last season's work have been grouped below so as to show the changes in the beet root during the progress of the sampling period. As stated before, the first samples were taken September 15, and the sampling was continued in case of three of the varieties on the main field, eastern and western halves, until the ground was frozen hard; the averages given after October 25, therefore, only include sets of three samples each; the others include series of thirteen analyses in case of main field, eastern half, and western half, both parts; ten analyses in case of the government plat, and fourteen analyses in case of the marsh field.

Changes in beets toward and after maturity, 1897.

Date of sampling.	Per ct. root of whole plant.	Wt. of beets.	Sugar in juice.	Purity of juice.
		Lbs.	Per ct.	Per ct.
	Main field, eastern half.			
Sept. 15 ...	57	.50	14.99	81.3
Sept. 25 ...	72	.64	15.14	79.2
Oct. 5 ...	77	.73	13.93	78.0
Oct. 15 ...	79	1.10	14.75	78.9
Oct. 25 ...	84	1.50	12.43	71.4
Nov. 5 ...	70	1.20	11.75	68.3
Nov. 15 ...	76	1.17	12.49	70.1
Nov. 25 ...	87	1.07	12.99	70.8
	Main field, western half, sub-soiled.			
Sept. 20 ...	66	.87	14.47	79.9
Oct. 2 ...	71	1.02	14.37	78.9
Oct. 11 ...	68	1.11	14.88	78.5
Oct. 21 ...	77	1.23	14.09	79.1
Oct. 25 ...	72	.97	15.22	77.2
Nov. 5 ...	72	1.07	13.54	79.6
Nov. 15 ...	70	.71	15.04	75.9
Nov. 25 ...	80	1.11	14.03	75.9
	Main field, western half, not sub-soiled.			
Sept. 20 ...	65	.65	13.40	77.5
Oct. 2 ...	73	.72	14.35	76.5
Oct. 11 ...	73	.67	15.46	79.3
Oct. 21 ...	77	.72	13.36	79.4
	Main field, government plat.			
Sept. 20 ...	70	.63	15.75	84.1
Sept. 27 ...	72	.71	16.90	82.2
Oct. 11 ...	73	.87	16.97	82.1
Oct. 25 ...	81	.81	17.41	80.8
Nov. 5 ...	....	.96	15.59	81.5
	Marsh field.			
Sept. 20 ...	71	.61	13.43	78.7
Oct. 2 ...	78	.73	14.24	77.4
Oct. 11 ...	73	.65	14.91	82.3
Oct. 21 ...	78	.82	13.80	81.3

The sub-soiled beets on the western half of the field produced the richest beets, and as we have seen the largest yield per acre. The low results obtained in case of the eastern half of the plat are doubtless attributable to at least two causes, the shallow plowing and the weedy condition of the field. It required continuous cultivation and hoeing between June 15 and July 27 to keep the weeds in check, and the loss of available plant food to the beet crop from this source naturally affected the quality as well as the yield obtained.

Changes in beets during storage.—The beet samples taken at harvesting time were stored in the basement of the barn or of the Agricultural Hall (marsh beets) and were analyzed twice during November and once during December, to find the effect of the gradual wilting of the beets on the percentage of sugar in the juice. The figures given in the following table are averages of all analyses made of beets of the same origin. The outside door of the barn basement was kept open until about Dec. 1, so that the beets were practically kept at outside temperature up to this time; the marsh beets were stored at a considerably higher temperature, and show the effect thereof in the larger decrease in weight and increase in the sugar content of the juice.

Changes in beets during storage.

DATE OF ANALYSES.	MAIN FIELD, EASTERN HALF. (Av. of 13 analyses.)			MAIN FIELD, WESTERN HALF. (Av. of 13 analyses.)			MARSH FIELD. (Av. of 17 analyses.)		
	Wt. of beets.	Sugar in juice.	Purity of juice.	Wt. of beets.	Sugar in juice.	Purity of juice.	Wt. of beets.	Sugar in juice.	Purity of juice.
	lbs.	per ct.	per. ct.	lbs.	per ct.	per ct.	lbs.	per ct.	per ct.
Oct. 29.........	1.75	14.77	73.3	1.37	14.53	74.3	1.08	13.74	75.3
Nov. 15.........	1.32	15.49	73.9	1.08	15.98	74.9	.79	15.97	73.9
Nov. 30.... ...	.96	15.92	72.6	.91	15.19	73.7	.61	18.31	74.4
Dec. 30*.......	.75	15.80	72.8	.76	15.48	72.2	....	....	....

*Averages of nine analyses.

As the beets wilt, their weight of course decreases, and the juice increases in richness; this change is accompanied by a decrease in the purity of the juice, which becomes quite marked in case of greatly wilted beets. The results presented above suggest that wilted beets, which have not been kept long enough to undergo serious changes due to oxidations in the beet itself, may show an increase in the sugar content of the juice of even five per cent. above what the beets would have analyzed shortly after being pulled. Analyses of wilted beets should therefore not be accepted as a correct statement of the sugar content of beets grown in any locality, but should be discounted by one per cent. or more according to the degree of wilting.

SUMMARY.

1. The investigation as to the culture of sugar beets in Wisconsin conducted during the past year confirms the results of the work done in this line during three previous seasons, and shows that beets of a high sugar content and a good purity can be grown in our state, provided the crop is given the care and attention which it requires; the yield of beets obtained will be as large as that secured in other places under similar conditions.

2. The Lake Shore region and adjoining counties, and the northwestern counties of the state have given the best results as regards the quality of beets raised. The other parts of the state, which lie either in the driftless area or in the sandstone region directly north of this area, seem on the whole less adapted to sugar beet culture unless manure or artificial fertilizers be applied to the soil, and particularly lime fertilizers, since the soils in these regions are likely to be deficient in lime.

3. The number of samples of sugar beets analyzed at this Station during the past season was 2,227; of these samples, 1,663 were received from sixty-eight different counties in the state; 97 were from forty voluntary substations established in different counties for the culture of sugar beets, and the rest were samples grown on our University farm.

4. The average sugar content of 1,663 beet samples forwarded for analysis by farmers located in different parts of the state was 12.67 per cent. sugar in the juice, with a purity of 74.1 per cent. The average of four years' analyses came at 12.70 per cent. and 74.8 per cent. purity. The average estimated yield of beets per acre was 13.6 tons (mean of 1,103 reports).

It must be borne in mind that these results were obtained with beets largely grown by farmers who had no previous experience in raising sugar beets, and who therefore often neglected points of vital importance in the culture of the crop, such as deep plowing, careful preparation of the seed bed, close planting, thorough weeding and cultivation, etc. Only about eight per cent. of the farmers who forwarded samples for analyses during 1897 had previously grown sugar beets.

5. The maximum analyses obtained for beets grown in the various counties during 1897 ranged from 11.50 per cent. (Green Co.) to 19.10 per cent. (Waukesha Co.), with an average of 15.97 per cent. sugar in the juice and 80.1 per cent. purity. The average of all analyses made of sub-station beets, as harvested, was 15.22 per cent. of sugar, with a

purity of 80.4 per cent. The average yield of beets obtained at these stations was at the rate of 29,850 pounds per acre, and the calculated yield of sugar per acre therefore about 4,200 pounds. The average expense of growing an acre of sugar beets was $28.73 (mean of 28 reports).

6. The work done at the University farm included tests of different kinds of imported and domestic seed, experiments with high-grade sugar beet seed made under the auspices of the U. S. Department of Agriculture, and a fertilizer experiment with beets on marshy land. For details of this part of the investigation and for a statement of the main results obtained, the reader is referred to pages 192-206 of this report.

COMMERCIAL FERTILIZERS.

F. W. WOLL.

I. ANALYSES OF LICENSED COMMERCIAL FERTILIZERS.

The results of the analyses of fertilizers licensed to be sold in the state during the current calendar year are given in the following. The subject of commercial fertilizers was discussed in some detail by the writer in Bulletin No. 49 of our Station: *The Maintenance of Soil Fertility; Commercial Fertilizers*, which bulletin was largely reprinted in our Thirteenth Annual Report. Persons desiring information in this line who have not received and preserved the report referred to, may obtain copies of Bulletin No. 49 upon request, as long as the supply on hand lasts.

The explanations as to fertilizer analyses and technical terms, given in the bulletin, will doubtless be of service to those unfamiliar with this subject. It has been thought well to repeat in this place a few explanatory remarks concerning the fertilizing elements contained in materials used for the purpose of maintaining or restoring the fertility of our land. These main fertilizing ingredients are nitrogen, phosphoric acid and potash.

Nitrogen may be present in fertilizers in three different forms, as *nitric*, *ammoniacal*, or *organic nitrogen*. The first two forms of nitrogen are of most immediate value to crops, since they are easily soluble and may be readily assimilated by plants. Organic nitrogen is the form of nitrogen found in fertilizers of vegetable and animal origin. Some of these, like leather or woolen scraps, hoofs, horn shavings, etc., possess very little value as fertilizers, being insoluble and but slowly decomposed in the soil. The fertilizer laws of many states do not recognize nitrogen contained in materials of this kind as of any value. *Nitro-*

gen in an available form means nitrogen supplied in nitrates, ammonia salts and organic compounds of easily decomposable character, like dried blood, tankage, cotton seed meal, etc.

Potash is always soluble in water in the compounds used as potassic fertilizers. The results of the analyses are figured on basis of the content of potassium oxid (K_2O).

Phosphoric acid (P_2O_5) may be found in commercial fertilizers in one or more of four different forms, viz.: in *mono-, di-, tri-,* and *tetra-calcium phosphate;* it is determined as *total,* or as *soluble, reverted* and *total phosphoric acid.* The soluble and reverted phosphoric acid include the phosphoric acid of mono- and di-calcium phosphates, respectively; the difference between these and the total phosphoric acid gives the insoluble phosphoric acid, contained in tri-calcium phosphate. The phosphoric acid in *tetra-calcium phosphate* (basic slag) is largely soluble in ammonium-citrate solution (*reverted phosphoric acid*). *Available phosphoric acid* means the sum of the percentages of the water-soluble and the reverted (ammonium-citrate-soluble) phosphoric acid, and represents the phosphoric acid of immediate value to plants.

The methods of analyses followed in the chemical work of our Station are those adopted by the Association of Official Agricultural Chemists; the methods are revised from year to year at the annual conventions of the association.

VALUATION OF FERTILIZERS.

The cost of commercial fertilizers in the market is governed by the laws of supply and demand, as is that of all other commodities. Raw materials and chemicals containing one or two fertilizing ingredients furnish data for the calculation of the average cost of these ingredients in commercial fertilizers. Since the prices of the different fertilizing materials vary somewhat from time to time according to the condition of the market, the calculations must be revised at intervals. The average retail prices of raw materials and chemicals in the large eastern fertilizer markets for the six months preceding March each year are calculated by a number of eastern experiment stations, and the cost of the different fertilizing ingredients which commercial fertilizers on the market contain, is obtained on basis of these figures; these values have been adopted by the Station in this year's work, as they will nearly correspond with the prices of fertilizing materials in our main fertilizer markets.

The trade values of fertilizing ingredients in raw materials and chemicals for the current year are as follows:

	Cents per lb.
NITROGEN—	
in ammonia salts	14
in nitrates	13
ORGANIC NITROGEN—	
in dry and fine ground fish, meat, blood, and in high-grade mixed fertilizers.	14
in cottonseed meal, linseed meal and castor pomace	12
in fine ground bone and tankage	13½
in coarse bone and tankage	10
PHOSPHORIC ACID—	
soluble in water	4½
soluble in ammonium citrate	4[illegible]
in dry fine-ground fish and in fine bone and tankage	4[illegible]
in coarse bone and tankage	3½
in cottonseed meal, linseed meal, castor pomace and wood ashes	4
insoluble (in ammonium-citrate solution), in mixed fertilizers	2
POTASH—	
as high-grade sulfate, and in forms free from muriate	5
as muriate	4¼

Following the practice adopted by the Pennsylvania Department of Agriculture, the valuation prices of the fertilizers licensed to be sold in our state have been calculated by adding to the actual cost of the fertilizing ingredients contained therein, the average expense of placing the fertilizers on the market, viz.:

Mixing	$1.00 per ton.
Bagging	1.00 per ton.
Agent's commission	20 per cent. of retail cash value of ingredients.
Freight	$2.00 per ton.

It must be remembered that the valuation placed on the various fertilizers by this method is a *commercial* and not an *agricultural* one, and shows the average retail cash price of the different fertilizing ingredients plus the cost of placing the fertilizer on the market; the *agricultural* value of a fertilizer depends on a number of conditions beyond the control of the seller, such as the need of the soil or the crop of the particular fertilizing ingredient or ingredients in question; the judgment used in applying the same, as to methods, time and quantities used; conditions of weather, etc.; the agricultural value of a fertilizer, in other words, will vary according to the season and according to the intelligent application of the fertilizer; one farmer may derive full benefit from the use of a fertilizer, while to another it may be money thrown away. It is therefore evident that only a commercial valuation of fertilizers is ever possible; this will enable persons to compare the different fertilizers offered for sale and will assist them in deciding which are the most economical ones for their purpose.

ANALYSES OF LICENSED FERTILIZERS IN WISCONSIN DURING 1898.

The following manufacturers have taken out a license for the sale of the brands of fertilizers given, in this state during the current year, according to laws of Wisconsin of 1895, Chap. 87.

Station No.	Name of Manufacturer.	Name of Brand.
24	Currie Bros., Milwaukee, Wis.	Currie's Complete Fertilizer for Lawns, Hay and Pasture.
25	Hofland & Tilleson, Menomonie, Wis.	"Best of All" Fertilizer.
26	Darling & Co., Chicago, Ill.	Darling's Farmers' Favorite.
27	Darling & Co., Chicago, Ill.	Darling's Chicago Brand.
28	Darling & Co., Chicago, Ill.	Darling's Pure Ground Bone.

Analyses of licensed fertilizers in Wisconsin, 1898.

Station No.	NAME OF BRAND.	Moisture.	NITROGEN.		PHOSPHORIC ACID.							POTASH.		Valuation per ton.
			Found.	Guaranteed.	*Soluble.*		Reverted.	*Available.*		*Total.*		Found.	Guaranteed.	
					Found.	Guaranteed.		Found.	Guaranteed.	Found.	Guaranteed.			
		pr. ct.	pr. ct.	pr. ct.	pr. ct.	pr. ct.	pr. ct.	pr. ct.	pr. ct.	pr. ct.	pr. ct.	pr. ct.	pr. ct.	
24	Currie's Complete Fertilizer for Lawns, Hay and Pasture...........	2.12	4.39	4.3	.58	....	5.08	5.66	5.5	12.33	12.0	8.18	8.0	36.20
25	"Best of All" Fertilizer..............	3.89	3.34	3.3	4.18	4.0	6.36	10.54	....	16.07	16.0	....	....	28.89
26	Darling's Farmers' Favorite....	6.25	3.83	2.8	2.73	....	4.56	7.29	8.0	13.40	13.0	4.97	4.0	32.60
27	Darling's Chicago Brand.............	6.13	3.15	2.0	3.38	....	2.36	5.74	7.0	12.16	12.0	3.68	1.0	27.74
28	Darling's Pure Ground Bone..........	4.24	3.02	2.4	....	....	....	....	....	24.64	23.0	....	....	37.50

The Station analyses of the brands given are shown in the preceding table. According to section 1 of our Fertilizer Law, each manufacturer "shall affix to every package of fertilizer sold . . . a statement of the following fertilizing constituents, namely: the percentage of nitrogen in an available form, the percentage of potash soluble in water, and the percentage af available phosphoric acid, soluble and reverted, as well as total phosphoric acid." The guaranteed composition of the licensed fertilizers is given in the table, and also the Station valuation according to the method explained in the preceding.

The mechanical analysis of the sample of bone meal included among the licensed brands of fertilizers gave the following results:

Mechanical analysis of bone meal.

Station No.	Brand.	Fine ground	Fine medium.	Medium.	Coarse.
		Per ct.	Per ct.	Per ct.	Per ct.
28	Darling's Pure Ground Bone	80.6	13.6	5.4	.4

II. FERTILIZERS FOR LAWNS.

The sale of commercial fertilizers in this state is very limited and is largely confined to the truck-farming districts tributary to Chicago and Milwaukee. Small quantities of fertilizers, notably cotton-seed meal, have also been applied experimentally from year to year in some tobacco-growing sections of the state, viz., the counties of Dane, Rock, Vernon and Crawford. Aside from what is used in these two special farming industries, practically no artificial fertilizers are sold in this state. The large majority of our farmers follow dairying or stock husbandry to a considerable extent or even as a main business and therefore produce on their own farms the manure needed for maintaining the fertility of their land. The quantities of valuable fertilizing ingredients sold off the land in the milk or cream, wool, stock, etc., are compensated for by purchase of concentrated cattle foods, like bran and oil meal, and the fertility of the farm thus kept up. In districts where grain-raising is still followed as a main reliance, only little live-stock is kept and but a small amount of farmyard manure is available and applied; as a result, the soil in these places is growing less productive every year, and these localities have not advanced with the general progress of the agricultural interests of the state.

There is another field for application of commercial fertilizers aside from strictly agricultural purposes which is capable of considerable development, viz., for the fertilization of lawns around residences and in parks. The Station every year receives letters of inquiry from private parties asking what kind of fertilizers to apply on their lawns and where to obtain them. Residents of cities would perhaps generally prefer to fertilize their lawns with proper artificial fertilizers if they knew where to get these and how to apply them, rather than use unsightly barnyard manure, with the chances in so doing of introducing new weeds on their lawns. The present short article is written with special reference to this class of people who want to learn the main points as to the kind of fertilization required to make or preserve a healthy growth of herbage on their lawns and the best methods of applying the fertilizers.

Speaking of the selection of grasses for lawns, F. Lamson-Scribner, Agrostologist of the U. S. Department of Agriculture, says:* "A perfect lawn consists of the growth of a single variety of grass with a smooth, even surface, uniform color, and an elastic turf which has become, through constant care, so fine and so close in texture as to exclude weeds, which, appearing, should be at once removed. Briefly, such a lawn may be secured by thorough preparation of the soil and the application of suitable fertilizers; by seeding with pure seed of the highest quality; by proper attention to irrigation and the maintenance of fertility; by the prompt removal of weeds, and, finally, by the frequent and intelligent use of the roller and lawn mower."

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* Year Book of the Department of Agriculture, 1897, pp. 355-372.

Ordinarily, however, a mixture of seeds are used in making lawns, since these will form a satisfactory sod more quickly and with less chance of failure than any one kind of seed. The following lawn mixture will be found well suited to the soils and climatic conditions of our state: one-third, by weight, of June grass, red top, and white clover. On high and dry land, red top should be omitted as it will not grow on such land anyway, and only June grass and white clover sown, in the proportion of 5 to 1 (by weight). The amount of seed required per acre of land will vary according to the character of the soil and the quality of the seed used; 3-4 bu., or about 60 lbs. of good seed is in general ample.

Where the lawn is made up largely of a single species of the grasses, as well as where a variety of grasses contribute to the herbage of the lawn it is necessary in fertilizing the lawn to supply a complete fertilizer containing all the main elements of plant food. One-sided fertilization produces abnormal plants or tends to crowd out some kinds of plants at the expense of others. To illustrate, applications of one-sided nitrogenous fertilizers, like nitrate of soda, cause the plants to grow rank, developing an undue proportion of stem and leaf growth which is undesirable in a fine lawn where a smooth, even surface with uniform deep green color is a prime condition. Nitrogenous fertilizers also have a tendency to crowd out the legumes in meadows or lawns grown from mixed seed and to favor the growth of the grasses proper.

Potash fertilizers, on the other hand, like Canada wood ashes or land plaster (which is indirectly a potash fertilizer) will favor unduly leguminous plants and bring in, for instance, white clover; potash and phosphoric acid fertilizers make plants grow more compact and tend to produce seed formation and premature ripening. For this reason, bone meal alone is not a proper fertilizer for lawns.*

Well-rotted farm yard manure to some extent fills the requirements of a proper lawn fertilizer, as it supplies the three valuable fertilizing ingredients generally called for by plants, nitrogen, phosphoric acid and potash, in about the right proportions. Many object to the use of barnyard manure on their lawns, however, for the reasons previously cited, and recourse has therefore to be taken to a mixture of fertilizing materials which will supply all the required elements of plant food in such proportions that the various parts of each component of the lawn and the various components themselves be stimulated to a healthy, normal development. A large number of different mixtures of fertilizing materials may be made up for this purpose from the common commercial fertilizers. Any of the fertilizers licensed for sale in this state (see page 213) may serve this purpose, except No. 28, which is a one-sided phosphoric acid fertilizer, and No. 25, which is a nitrogen- and phosphoric acid fertilizer.

A lawn fertilizer sent in during the past year by Mr. J. C. Currie, Superintendent of Forest Home Cemetery, Milwaukee, Wis., was found to have the following composition:

Nitrogen	1.68 per cent.
Phosphoric acid	5.86 per cent.
Potash	4.71 per cent.

The fertilizer is made up from a mixture of unleached Canada wood ashes, bone meal and nitrate of soda. Mr. Currie writes concerning the use and effects of this fertilzer:

"For a number of years I have experimented with various lawn fertilizers, some of them my own mixtures and others bought of several dealers, but the one I am now using appears superior to any previously tried. . . Applied at any season of the year when the grass is growing the result seems the same. I apply it at the rate of 6½ pounds per 100 square feet or about 2800 pounds per acre. It is mixed in the spring about three weeks before any of it is applied. One application is made each year, but I find it may be applied at any time during the summer with apparently good results when a weak and sickly growth of grass indicates impoverished soil."

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* The effects of various systems of one-sided fertilizations are illustrated in a most striking manner in the classical Rothamsted experiments on the Effect of Fertilizers on the Mixed Herbage of Permanent Meadow conducted more than twenty years in succession on the same land, to which persons interested in the subject are referred. (*Philosophical Transactions*, 1880-82.)

This fertilizer would doubtless prove still more effective by increasing the amount of nitrate of soda, making the mixture, for instance, two parts of wood ashes, one part of dissolved bone meal and two parts of nitrate of soda. If made up of fertilizing materials of good quality, this mixture will contain 6.8 per cent. nitrogen, 2.1 per cent. potash and 4.2 per cent. phosphoric acid. 750 pounds of this fertilizer will be required per acre and will supply 51 pounds nitrogen, 15¾ pounds of potash, and 31.5 pounds of phosphoric acid. These quantities approximately cover the amounts of fertilizing elements taken away from an acre of the lawn if this is kept closely cut throughout the season and the grass raked off the lawn as cut. For a small lawn, say 4,000 sq. ft., the quantity required of a mixed fertilizer like the preceding one would be about 70 pounds, or at the rate of nearly two pounds per 100 square feet.

A complete fertilizer as that given above should not cost over $35.00 per ton retail, or if sold in small quantities, say $2.50 per 100 pounds. Where wood ashes are not available, 30 pounds of muriate of potash, worth about 70 cents, may be used per acre in their place in the mixture; this cheapens the fertilizer somewhat, and the muriate has the additional advantage over Canada wood ashes of being of a quite uniform, definite composition, always containing about 50 per cent. of potash. The wood ashes, on the other hand, in addition to the potash which they contain, supply a small quantity of phosphoric acid and considerable lime.

It will be seen by comparison with the published table of the composition of licensed fertilizers in our state for the current year (see page 213) that the preceding lawn fertilizer is considerably richer in nitrogen than either of the three complete fertilizers given, and lower than these in phosphoric acid. The formula given is, however, made up with special reference to the fertilizer requirements of lawn grass and does not contain an undue proportion of any single component. It is a concentrated fertilizer and must be applied with a little care lest the nitrate contained therein injure the grass. The best method is to mix it thoroughly with three or four times its bulk of clean, black dirt before sowing it broadcast over the lawn, crushing all lumps so that it may be spread evenly. The spring and early part of the summer is the best time of year in which to apply artificial fertilizers on lawns.

THE RESUMPTION OF ROOT GROWTH IN SPRING.

E. S. GOFF.

The early spring root growth of perennial plants might be expected to have some practical bearing upon the operations of transplanting and early cultivation. To ascertain what this bearing may be, some observations were commenced in the latter part of March, 1898, upon the root growth of several species of trees and other plants growing on the Station grounds. These observations were chiefly made by excavating a short ditch near the point where the main roots of the plant under observation were supposed to terminate, and in the direction in which they were supposed to extend, and then washing out, by means of a gentle stream of water, some of the roots and root branches to their tips. This study developed some rather important points which, if not new to science, have been little applied in plant culture. Among these may be mentioned:

1st. *Root growth starts before stem growth* in many plants. As the result of numerous observations, the conclusion was reached that the resumption of root growth, or at least of root elongation, is indicated by a white and plump condition of the root tips that is very readily recognized. Prior to this resumption, the root-tips, in the plants examined, generally appeared brown and when examined under the lens, had a more or less reddish, translucent tint, but the newly-formed cells appeared white to the unaided eye, and nearly transparent under the lens.

Fig. 34 shows a portion of the roots of the red currant washed out on March 31. The buds at this time were but little swollen. As appears from the illustration, the new growth was already three inches long in some cases. At this time grass had commenced to grow slightly on south exposures and flowers of the soft maple had opened, but as a rule, the buds of trees had not perceptibly swollen.

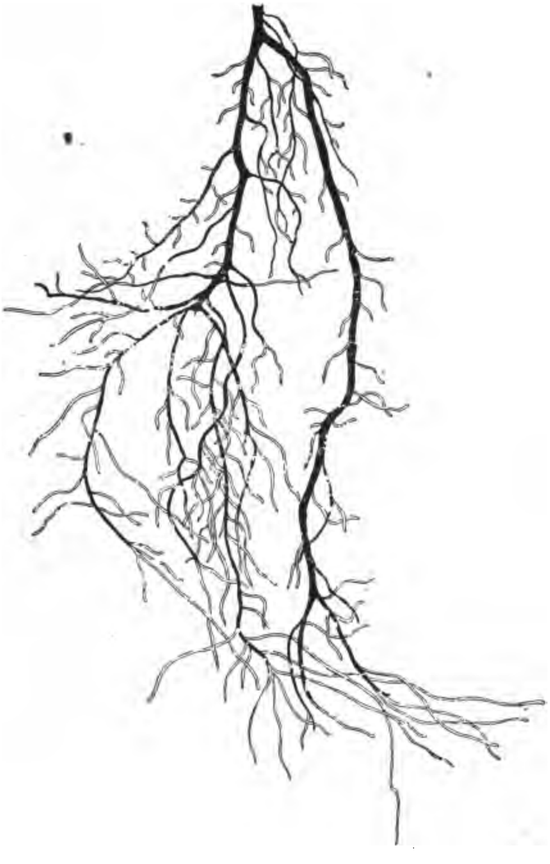

FIG. 34.—Showing sample of the roots of the red currant washed out on March 31. The parts of the drawing shaded black were of the preceding year's growth; the unshaded parts represent the new growth. Reduced one-half.

The root growth was found to have started more or less in advance of the buds in the Norway spruce, *Picea excelsa;* the White spruce, *Picea alba;* the Douglas spruce, *Pseudotsuga Douglasii;* the Colorado blue spruce, *Picea pungens; Abies concolor;* the American arbor vitæ, *Thuja occidentalis;* the Scotch pine, *Pinus sylvestris;* the hemlock spruce, *Tsuga Canadensis;* the Amure tamarisk, *Tamarix amurensis;* the sugar maple, *Acer saccharinum;* the apple, *Pyrus malus;* the pear, *Pyrus communis;* the morello cherry, *Prunus cerasus;* the choke cherry, *Prunus Virginiana;* the white birch, *Betula alba;* the Russian mulberry, *Morus alba;* the wild red osier, *Cornus stolonifera;* the Russian olive, *Eleagnus hortensis,* var. *Songorica;* the red currant, *Ribes rubrum;* the white currant, *Ribes nigrum,* and the gooseberry, *Ribes oxyacanthoides.* In none of these plants, however, was the root growth found to be so far in advance of the bud development as in the red currant. Fig. 35 shows a portion of the roots of a tree of the American arbor vitæ dug April 1, and Fig. 36, part of the roots of a Norway spruce tree dug April 15. At the latter date the buds of neither of these trees had swollen perceptibly.

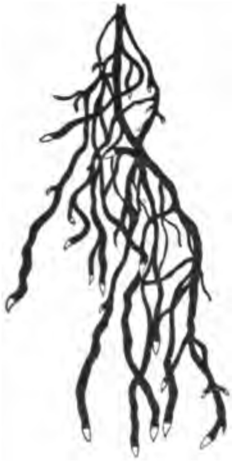

FIG. 35.—Showing roots of American arbor vitae washed out Apr. 1. Reduced one-half.

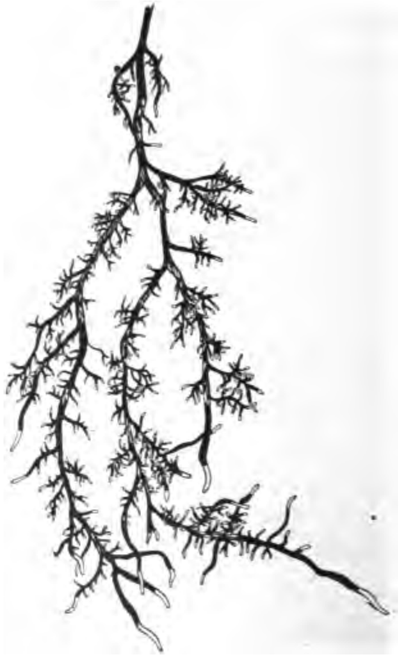

FIG. 36.—Showing roots of Norway spruce washed out Apr. 15. Reduced about one-half.

Some herbaceous plants apparently start root growth extremely early in spring. On March 22, roots of the strawberry and quack grass appeared to have made considerable growth. At this time the ground was free from frost in places most exposed to the sun's rays, but grass had not grown above ground to a visible extent.

Some plants apparently do not commence root growth earlier than bud growth. As late as May 4, the root tips of a vine of Worden grape had scarcely commenced to elongate, nor were the buds perceptibly swollen. It was observed at this time that the buds of the Ebony grape were somewhat swollen, and on the following day the roots of this variety were found to have started at some points as much as half an inch.

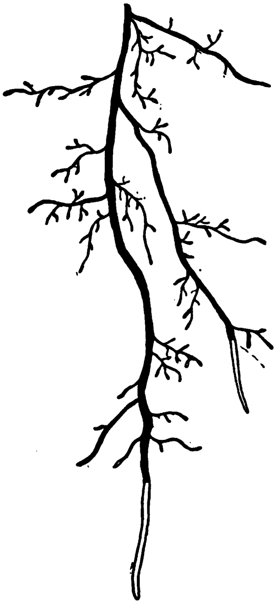

FIG. 37.—Showing roots of Norway spruce washed out on May 5. Reduced one-third.

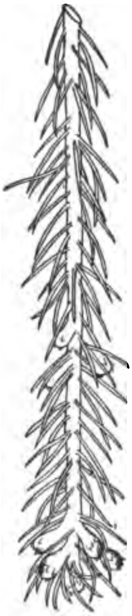

FIG. 38.—Showing buds of Norway spruce on May 5. Compare with Fig. 37, which shows root tips of same tree. Reduced one-half.

The root growth does not appear to advance as rapidly on the advent of warm spring weather as its early start would lead us to expect. On April 14, the new root growth of the plant of red currant examined on March 31 was apparently but about 5½ inches long, and on May 5, the roots of a Norway spruce tree appeared to have made less than 2 inches of new growth, as shown in Fig. 37. The development of the buds of the same tree at this time is shown in Fig. 38.

2. *Root growth is most vigorous at the apex of the main roots,* as appeared from observations made on plants representing a number of botanical species. Next to this, it is most vigorous at the apex of the principal branches of the main roots, and the earliness and vigor of starting diminishes as we recede from the growing points of the principal roots. In other words, the order and vigor with which the various parts of the roots resume growth in spring is very similar to that which takes place in corresponding parts of the stem. This gradation of growth is well shown in the illustrations of roots already referred to, and in the following measurements from a root of a seedling of the Early Richmond cherry washed out April 28. This root terminated in two very thick shoots, of each of which the new growth was at this time 2 inches long. At the base of these two shoots were 5 smaller shoots the combined length of which was 2¾ inches. Thus the total new growth at and just behind the apex amounted to 6¾ inches. The next branch of any considerable size farther back had grown 1⅛ inches at its apex; the next one 15/16 inch; the next ½ inch and the next two about ¼ inch each. Farther back than this very little growth had taken place. The diminution in the amount of growth as we recede from the apex was not so regular as this in all the roots examined, for as we shall see later, the depth at which the branches happen to grow in the soil has much to do with the earliness of their starting. It seems probable that this tendency of the growth to diminish as we recede from the main growing points is more fully wrought out in the roots than in the stem. It is well known that the roots of many plants extend much farther from the trunk than do the branches of the stem, which implies that the roots must grow correspondingly faster than the latter. The roots are not required to support themselves in the soil, hence they do not need to grow as strong as the branches of the stem and so are able to devote the more energy to extension in length.

As they tend to reduce the plant food in the soil as they proceed, they need to extend over a larger area than the stem to which food is brought by the freely-circulating air currents.

The vigorous resumption of growth in the apical portions of the root apparently starves many of the older branchlets, for the number of these rapidly diminishes as we follow back the main roots toward the trunk.

The early and vigorous terminal growth of roots would seem to have an important bearing upon the time that trees and other perennial plants should be lifted for transplanting. All root growth that occurs before the expansion of the leaves must act as a drain upon the stored nutriment of the root itself. Whatever terminal root growth is made before the plant is lifted is therefore a positive damage unless the apical part of the root is taken up with the rest, which is rarely practicable. The proper time to lift the plant would seem to be before the root growth has commenced; otherwise the lifted portion of the root has suffered more or less depletion of its reserve food, and is hence in a weakened condition. The effect is probably similar to that of the sprouting of seed potatoes before planting, which is well known to reduce the vitality of the tubers. The most favorable time for lifting perennial plants is probably in autumn, or very early in spring, and if the replanting cannot be performed at once, the roots may be temporarily planted ("heeled in") in soil, sand, sawdust or some other well-aerated and moist medium. The root growth that starts while the plants are heeled in will usually be at the apex of the branches that were uninjured in the lifting, and will have a better chance of being saved in the final planting than if the tree had been lifted immediately before the planting.

3. *Root growth in spring is most active near the surface of the soil.* This fact was brought out in many examples. The surface of the soil is first warmed by the sun's rays, hence the root tips nearest the surface first receive the impulse

of renewed life. Thus the parts of the soil from which roots are in a measure excluded during the dry weather of summer may serve as a feeding ground for them in early spring. This was strikingly shown in the currant and certain other plants. An inch of the surface soil washed off from an area of about 4 square feet near a vigorous plant of the Black Victoria currant during the latter part of April, revealed a multitude of delicate rootlets which would gladly have been shown in an illustration, but the effort proved a failure.

The very shallow depth of the earlier root growth of spring would seem to offer an objection to the early cultivation of currants and gooseberries, and other plants that commence growth especially early.

4. *Root growth starts in spring where it left off in autumn.*—A proposition has sometimes been published in horticultural publications to the effect that the fibrous roots of perennial plants die in autumn, and are renewed, on the resumption of growth in spring. I have not seen this statement in any work on botany, though it has appeared in some places that rank as good authority. Thus I find in Meehan's Monthly (1893, p. 72) the following definite statements: "It must not be forgotten in all lessons in practical fruit culture, that there are two classes of roots to trees; one are permanent and are truly roots, the others endure only one year, and are called fibres. When therefore, the term fibrous roots is used, it is calculated to mislead. There may be dozens of fine threads which are intended to make permanent roots, and which appear like fibres, but are not truly fibres in the sense already intimated. True fibres are annual, and are the feeders. They collect the food which goes to the nourishment of the main roots and branches, just as the leaves of a tree prepare the food which goes to the permanent shoots and branches. As in the case of the leaves, these usually die after a short period — usually a year."

I also find the following in a work entitled "Errors about plants," by Mr. A. A. Crozier (p. 100): "After it became known that roots absorbed food only at or near their extremities, the preservation of the smallest fibers in the removal of plants came to be considered a matter of almost essential importance. Further observation, however, showed that these fibres were easily destroyed by exposure to the air, and that during winter a large share of them died as a natural process, Then it came to be understood that while the ultimate fibres are of the utmost value during the growing season, they are of comparatively little use during the period of rest, when the plant is generally removed, and that, therefore, if the main root system is preserved in transplanting, down to roots the size of a pipe stem or less, the small fibres are easily restored by the plant if the soil and other conditions are favorable."

In the plants of which the roots were examined the past spring,* I failed to find any evidence of a general death of the finer roots. On the contrary, the new growth generally started from the identical tips where it ceased in autumn, as is clearly shown in the illustrations. Dead root tips were sometimes found, but these were emphatically the exception. The erroneous idea of a general death of the root tips has probably come from superficial observation. In many of the plants examined, the rootlets appeared dead to the naked eye, but on closer examination it was evident that only the outer bark-layer was really dead. Beneath this dark-colored and slimy bark-layer, the tissues were usually plump and in good condition. That the center of the roots was alive was shown by the fact that new growth promptly started at their tips. Sometimes this

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*Including in addition to those already named, the plum, *Prunus americana;* and white ash, *Fraxinus americana;* the purple beech, *Fagus sylvatica;* a willow, *Salix sp.;* Paule's double scarlet thorn, *Cratægus oxycantha;* the snowberry, *Symphoricarpus racemosus;* Thunberg's barberry, *Berberis Thunbergii;* the large-flowered syringa, *Philadelphus grandiflorus;* the fringe tree, *Chionanthus virginica;* the flowering dogwood, *Cornus florida;* the red-berried elder, *Sambucus racemosa;* and the Columbian raspberry, *Rubus neglectus*, var.

dead cortex was thick in proportion to the diameter of the root. It was generally thicker on the smaller rootlets than on larger ones, and was usually very readily removed. Fig. 39 shows a longitudinal section of a rootlet of American arbor vitae. The dead cortex is indicated by the heavy dark lines. The broader white part represents the new growth. The branches of this main root were not dead, and did not come off, when the dead cortex was removed. New branches of the root push their way through the dead cortex.

In some plants, as the red-berried elder, flowering dog-wood, large-flowered syringa, snowberry, fringe tree, white ash, choke cherry, Amure tamarix and white birch, the cortex was white or nearly so, and in the white ash, snowberry, choke cherry, and white birch it was firm and not easily detached, which suggested that it was probably alive.

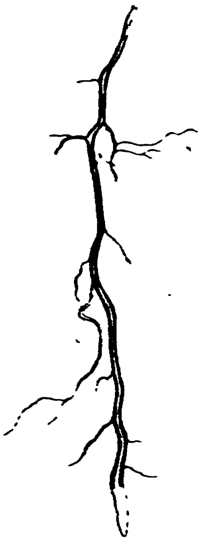

FIG. 39.—Showing longitudinal section of rootlet of arbor vitae in early spring. The heavy black lines represent the dead cortex; the white portion at the tip shows the new growth. Reduced one-half.

No evidence was brought out in this investigation to warrant the conclusion that the finer roots of plants may be wisely ignored in transplanting. It is undoubtedly true that these roots are usually short-lived under adverse treatment, but this fact should emphasize the importance of so handling the plant as to preserve the finer roots rather than be construed as a license for their wholesale destruction. The florist knows that a potted plant may be shifted, or planted out with far less check to the plant than occurs when the roots are removed from the soil in which they are established, and the nearer we can approach in transplanting to the methods practiced in shifting plants, the more highly will the transplanting art have been developed.

MORPHOLOGY OF THE STRAWBERRY PLANT.

E. S. GOFF.

The intelligent culture of any plant must necessarily be developed largely from the growth habit of the plant itself. The methods of potato culture differ from those of wheat culture mainly because the potato plant grows differently from the wheat plant. It follows that until we have learned the growth habit of a given plant we are not prepared to outline a rational system of culture for it.

The development of the strawberry plant through its different stages, and the comparison of these different stages of development with the corresponding ones in other plants, or to use a more concise term, the *morphology* of the strawberry plant, has been little studied, or at most has been little published. Indeed, the morphology of the strawberry plant is more complicated than that of many larger plants. It is thought, therefore, that a brief outline of this subject will enable the strawberry grower to practice a more intelligent system of culture.

While the numerous species of flowering plants differ widely in appearance and manner of growth, they all have certain points in common. They all have a root and a stem, for example, more or less clearly defined, and each of these parts has one or more growing points in which, during the growing season, rapidly-dividing cells are forming new plant tissue to be later differentiated into the various organs which are developed in the lines that best enable the plant to cope with its environment. The stem in the flowering plants possesses more or less clearly defined joints, or nodes, at which the leaves normally appear, if at all, and just above the base of each leaf a bud is normally developed, destined under favorable conditions, to form a branch. The spaces between the nodes of the stem (internodes) vary greatly in the development they undergo in different plants, and even in different parts of the same plant. The internodes of the higher plants may be likened to concentric telescope tubes that may remain closed or may be drawn out to a considerable length. In some plants, as the grasses, the internodes are greatly lengthened in proportion to the diameter of the stem; in others, as the plantain, the internodes are little developed.

The stem of the strawberry plant.—In our study of the strawberry plant, the stem chiefly interests us, since the peculiarities of this plant, that render it so different from our other fruit plants, lie chiefly in this organ.

Most strawberry growers would say at first thought that the strawberry plant has no stem. Indeed some botanical descriptions call it "acaulescent," which means stemless. But the strawberry plant has a stem as truly as the corn plant, though it is developed in a very different manner. This stem has its nodes at which leaves and buds are formed, and these buds develop under favorable conditions into branches as in other plants. Since the stem in the strawberry plant is herbaceous, i. e., not woody, it is better able to endure the winter, if developed very low down, where it will be protected by the falling leaves in autumn, and it is perhaps this fact that enables the strawberry plant to thrive in such cold climates. The internodes, therefore, remain undeveloped, except in certain parts of the stem where, as we shall see later, a definite advantage is gained by lengthening of the internodes. The stem is, therefore, very short, and as it serves as the chief repository for the food formed by the leaves in summer, it is rather thick also. Fig. 40 shows the stem of a strawberry plant two years old. The bases of the leaves and runners that grew last season have been removed. The closely-crowded nodes cannot be made out individually, but we know they are there because we know that leaves are formed at the nodes and the leaf scars are apparent. At the top are seen the growing shoots of the current season.

A leaf of the strawberry plant is shown in Fig. 41. The thin, pointed appendages at the base of the leaf-stem are called stipules. As the new leaves are developed, these stipules remain wrapped about the delicate growing point and serve as a protection for it. The stipules grow larger as the leaf increases in size, and wrap themselves about the stem, and as the successive leaves develop very close together, the stem is always inclosed in a mantle of stipules several layers in thickness, which protects it from sudden changes in temperature.

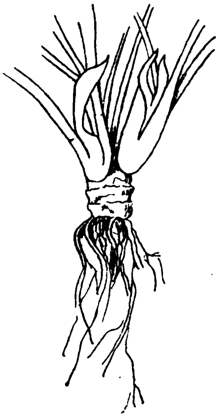

FIG. 40.—Showing stem of two-year-old strawberry plant; i. e., the part between the roots and base of leaf stalks. Slightly reduced.

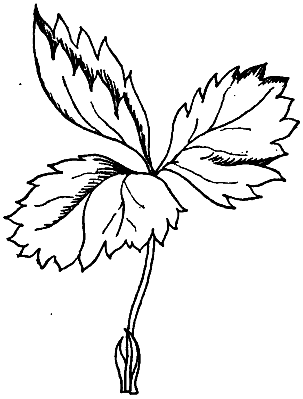

FIG. 41.—Showing leaf of the strawberry plant. Slightly reduced.

At the axil of the leaf *a* (Fig. 42.), a bud was located which has grown out into a long slender branch or runner. In this case there was a special object to be gained by the lengthening of the internodes of the branch below this bud, hence these have been greatly elongated. The seeds of the strawberry are quite small, and the plantlets that grow from them are very delicate. As the wild plant grows in uncultivated ground, it would be liable to extermination if it had no other means of multiplication than by its seeds, hence, in the struggle for existence, a more reliable method has been developed. By the elongation of the internodes just beneath the terminal bud, the latter is pushed out some distance from the parent plant and as the bud develops leaves, the weight of the whole causes it to settle to the ground, bringing its lower sides in contact with the earth where moisture stimulates the production of roots which soon find their way into the soil, and a young plant is the result.

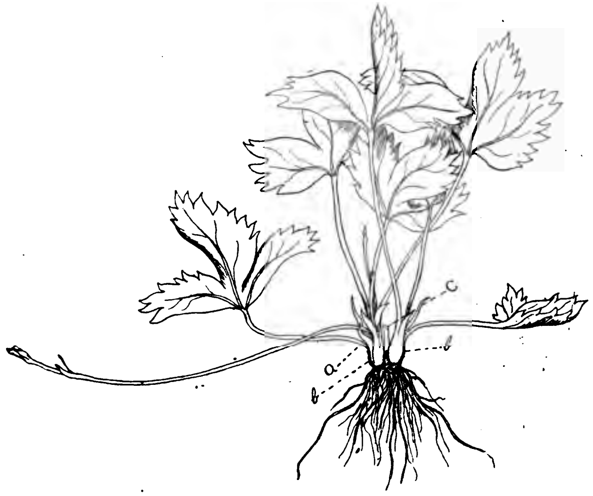

FIG. 42.—Showing strawberry plant in its second year. *a*, runner starting from axil of a leaf; *b–b*, branches of stem; *c*, base of flower stalk. Reduced one-half.

Between the large .terminal bud at the end of the runner, shown at *a* (Fig. 43), and the place where the runner leaves the parent plant, is a small leaf-like appendage *b*, which on close examination is found to be a not-fully-devoloped leaf.

We know that a leaf is commonly formed at a joint or node of a young stem, and we may infer, therefore, that this point marks a node of the runner, and if we pass the fingers along the runner we readily feel the slightly enlarged node at this point. In most plants a bud is developed in the axil of a leaf, i. e., at a node of the stem, and we may look for a bud at this point, which we may readily see by turning back the leaf. At *a* (Fig. 44), this bud is seen further developed. Runners of the strawberry often branch, and the branch always starts at this first node from the parent plant. The object of this node is doubtless to make a place for a reserve bud that can develop in case the terminal bud fails. If we trace the runner a little farther (Fig. 44), we find another partially-developed leaf at *b*, and in the axil of this leaf, another branch (c) is pushing out. We know this to be a branch instead of the continuation of the original runner because it comes from the axil of a leaf. If it were the original runner continued, the leaf would be on the other side of the runner.

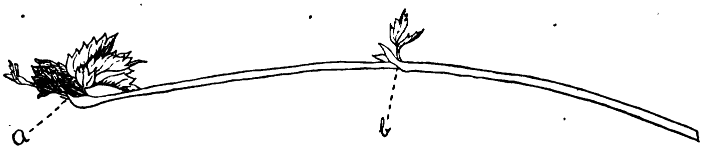

FIG. 43.—Showing a partially-developed runner of strawberry plant; *a*, terminal bud; *b*, undeveloped leaf at first node. Reduced one-half.

Just behind the base of this branch is a cluster of more or less developed leaves from the lower part of which the rootlets (d) proceed and within which is the growing point or apex of the original runner. Thus we see that the runner of the strawberry is a branch consisting of a terminal bud and two nodes, separated by rather long internodes.

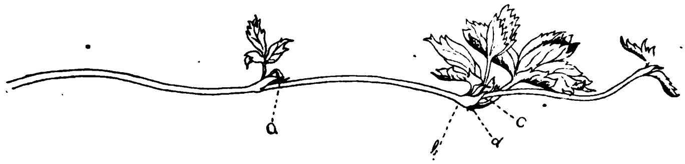

FIG. 44.—Showing runner further developed. *a*, bud at first node; *b*, partially developed leaf at second node; *c*, branch starting from second node; *d*, rootlets starting from second node. Reduced one-half.

This terminal bud is similar in all respects except age to the terminal bud of the parent plant. The runner that continues beyond the first-formed plant is a branch of the first runner, starting from its second node, and growing precisely like the first runner. The second runner doubtless draws its nourishment largely from the parent plant, for it is generally quite well formed before the young plant is rooted.

The runners begin to form as early in spring as the new leaves begin to grow, though they do not attain sufficient length to attract attention until some time afterward. Although a runner is normally formed in the axil of every leaf, it sometimes fails, hence there may be fewer runners than leaves. As the season draws to a close, one or more buds in the axils of the youngest leaves are overtaken before they have had time to develop into runners: As a rule the internodes of any plant located beneath vegetative buds (i. e., buds that are not flower-buds) and that are not fully developed at the close of the growing season, do not increase in length the following season. Those overtaken vegetative buds, therefore, do not become runners the next year, but the internodes remain undeveloped and they become branches of the main stem (b b, Fig. 42).

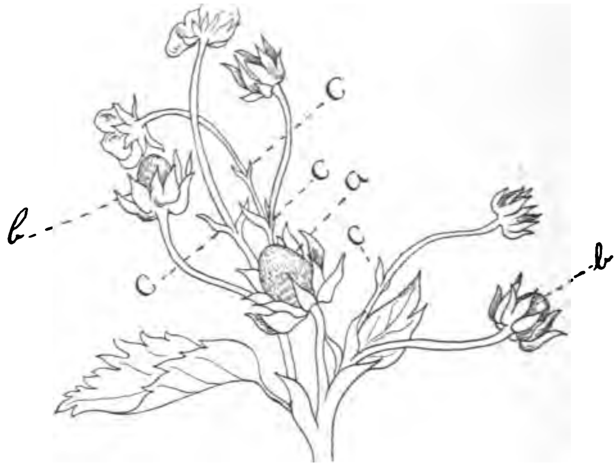

FIG. 45.—Showing fruit stalk of strawberry. *a*, fruit forming terminus of stalk; *b–b*, fruits terminating primary branches; *c–c*, fruits terminating secondary branches. Reduced one-half.

We now come to a most interesting departure from the growth process thus far traced. The following spring these incipient branches begin to form leaves rapidly with buds in their axils that are to form runners, i. e., they behave as the main stem did the preceding year. At the same time the terminal bud of the preceding year and a few axillary buds immediately beneath it that are still younger in development than the branch buds above mentioned, push upward and open flowers (C. Fig. 42; Fig. 45).

It is important that the flowers be projected above the leaves far enough to attract insects that can aid in pollination, hence for this special purpose the internodes immediately beneath the flower-buds, that had up to this time remained undeveloped, elongate rapidly in early spring.

The earliest fruit of the cluster, and commonly the largest one, is the fruit that forms the terminus of the main stem (a, Fig. 45). The next to ripen are the berries that terminate the primary branches (b b). Those that terminate the secondary branches mature next, etc. The analogy of these branches with the runners is shown by the fact that each one of them starts at the axil of a leaf, and has a node between the flower and its point of origin as indicated by the pair of undeveloped stipules. (c c).

When are the flower-buds formed?—We cannot say positively when the initial flower cells are formed, for we are unable to distinguish flower cells from others in their early stages. They may be formed at the time the other cells of the growing point are formed. If this is the case, the terminal bud of every seedling strawberry plant and of every strawberry runner contains special flower-cells that will one day develop into flowers if the growth continues, and the final opening of the flowers is simply the more or less complete fulfillment of a preärranged plan. Or the cells of the growing point may be at first all of one class, which are later differentiated into special cells through the influence of environment. Practically, it makes little difference to the strawberry grower which of these propositions is correct, for we know in either case that the number and vigor of the flowers that ultimately form depend very largely upon the conditions of growth previous to and during their formation, and it is the grower's business to find out and to provide for the favoring conditions.

Whenever the initial flower cells are formed, we know that the elaboration of these cells into flowers takes place mainly after the development of runners has ceased, because the branches that form flowers beneath the terminal bud are later in the order of their development than the later-formed runners. It seems probable that the elaboration of the flowers takes place rather late in autumn when growth is declining, and that the rapid development of the flower stalk in spring is but the expansion of the autumn-formed cells, as is the case with most early flowering plants.

Since the flower stalk is the terminal or leader shoot of the plant, it follows that the seedling strawberry plant and the young runner plant, forms but one flower-stalk the first season that the plant blooms* and there is but one flower stalk to a single branch of the main stem; but as the stem of a plant more than one year old may have more than one branch, so an old plant may have more than one flower-stalk.

Stooling of the main stem.—It is well known that persistency in removing the runners of the strawberry plant causes the formation of a large crown with numerous leaves, followed by many flower stalks the following spring. This is due to branching of the main stem from adventitous buds, and is the common result of excessive pruning in all plants. Very vigorous plants probably sometimes stool to a slight extent when the runners are not removed.

The life period of the strawberry plant.—The normal branching of the main stem of the strawberry plant toward the close of the growing season provides for the indefinite prolongation of its life. But these branches are put forth near the top of the stem, hence the tendency is to project the stem higher above the soil each season, which exposes the crown more to the weather. As the stem increases in length new roots are formed above the older ones, and the younger roots appear to be most vigorous so long as they are well covered with soil. But as the plants attain age, the later-formed roots are so shallow in the soil that they are likely to perish in dry weather. This, coupled with the increasing exposure of the crown to the weather, results sooner or later in the death of the plant.

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*Exceptions to this rule apparently sometimes occur, just as there are sometimes two or more leaders to a coniferous tree.

Cultural applications suggested by the foregoing study.—The incipient flower stalk, which appears to be formed in autumn, is located at a part of the stem that is most exposed to the rigors of winter and the vicissitudes of spring and autumn weather. How important is it then that the crown of the plants should be protected by a covering of non-conducting material! And this material should be applied before hard freezing of the ground in autumn.

The short, thickened stem of the strawberry plant is the reservoir where its surplus food is stored. The fountain that supplies this reservoir with food is mainly the leaves. The surplus food is drawn upon to form the first leaves in spring, the flower-stalk, the flowers, the fruit and the runners until these have rooted. The number and size of the fruits will depend much upon the stock of food that is not consumed by other parts. How important it is then that the leaves should be guarded against damage from insects and fungi, and that sufficient water should be provided in dry weather to enable them to perform their work without restriction.

The runners of the strawberry plant cannot provide all of their own nourishment until their roots are established in the soil. In dry weather, therefore, when the runners do not root readily, they are doubtless detrimental to the plant, since they are poorly supplied with leaves, and usually grow rapidly. Such runners should either be aided to root by planting, or else they should be removed.

Since the maturing fruit requires large amounts of water, and since the forming runners need water to distend their rapidly multiplying cells while they discharge some water by evaporation, it would probably be best to remove the runners from bearing plantations until the fruiting season is over, at least, in dry weather. Since the rows are commonly much narrowed after fruiting, all runners formed prior to the narrowing are so much waste energy to the plant.

The removal of the runners throughout the whole season does not seem warrantable, for as we have seen, this promotes excessive stooling of the stem, giving too little room for root development.

Runners that root late in autumn do not have time to stock their stems with a sufficient supply of reserve food and hence are not able, as a rule, to form vigorous flower-stalks the following spring. It is probably better to cut off the later-formed runners and thus enable the plants to devote their declining energy to stocking their stems with food and to the elaboration of their flower cells.

Liberal top dressing with fine manure or very fertile soil after the fruiting season would seem to be the most rational method of fertilizing the strawberry plantation. The most active younger roots will thus be given abundant nourishment and will be at the same time protected in a measure from excessive heat. The crown of the plant, that contains the incipient flower stalk, will also be guarded from excessive changes of temperature and dryness. The strawberry bed might doubtless be permanently maintained by gradually raising the surface with frequent top dressings.

The practice of mowing strawberry beds after the fruiting season and burning the cut-off material is warrantable as the most effectual means of destroying insect and fungous parasites. The early-formed leaves have by this time become more or less clogged with useless mineral matters that hinder their normal functions and render them liable to fungus attack, while the leaf-roller and certain other insect enemies are at a stage that renders them especially vulnerable to this treatment. It is doubtful, however, if burning the cut-off material upon the strawberry rows can be recommended, for if the heat thus produced is beneficial in destroying weeds and insects in the rows, it must injure the stems of the strawberry plants to a corresponding degree. It is probably better to rake the rows clean of all dead leaves and other litter and to burn this material elsewhere. If the ground is dry, it is important to apply abundant water or else to mulch the mowed rows with clean litter, otherwise the unbroken rays of the sun upon the heretofore protected crowns must prove more or less harmful.

METHODS OF IMPROVING THE EFFICIENCY OF SPRAYING APPARATUS.

E. S. GOFF.

The spray pump is slowly but surely becoming recognized as a necessary part of the orchard and garden outfit. Although its development has extended over nearly twenty years, few who have used it extensively will admit that even its most improved forms are fully satisfactory. The constant tendency of the heavier part of the spraying mixture to settle to the bottom of the reservoir has been the chief hindrance to its successful working. The most common spraying mixtures, as Paris green and water and the Bordeaux mixture, settle rather rapidly in still water with the result that the liquid constantly tends to increase in density toward the bottom of the reservoir. Unless kept mixed by frequent stirring it is difficult or impossible to secure a uniform distribution of the materials. The mixture is liable to be so weak as to be inefficient or so dense as to be sprayed with difficulty and even to endanger the plants. Many devices intended to prevent this trouble are in use but few if any of them are more than partially satisfactory. Many who have purchased a spraying pump are aware of this defect, but do not know how to remedy it, and do not feel able to buy a new one, even if they could find one free from the objection.

The method of spraying kerosene directly with water, thus dispensing with the trouble of making a kerosene emulsion, originated at this Station and was first published in 1891. The success of this manner of using kerosene for insects has now become generally recognized, but thus far no simple plan has been devised by which it may be applied to any of the common spraying pumps now in use. The writer has been endeavoring to devise simple attachments that may be used on the ordinary spraying pump, and that would prevent the annoyance due to settling of the spraying materials, and would also enable kerosene and water to be sprayed together in sufficiently uniform proportions to ensure both safety and economy. After many experiments the devices described below are offered with the belief that they fully accomplish the objects sought.

Attachment to secure uniformity in spraying.—The spraying pumps heretofore invented have regarded it necessary to draw the liquid to be sprayed from the bottom of the reservoir only. In order to spray with uniformity materials that constantly tend to settle, like the Bordeaux mixture and Paris green and water, it was therefore necessary to keep the whole mass of the materials in the reservoir in circulation from the bottom to the top. The mere agitation of the contents of the bottom of the reservoir does not suffice to lift these contents to the top when the reservoir contains any large amount of the materials, as appears conclusively when the experiment is made in a glass vessel. It is not strange, therefore, that the so-called "agitators" have failed. Even if they accomplished the purpose, it would require too much power to operate them.

In the device here described, the material as it is pumped out of the reservoir is taken from practically the whole depth at the same time. It does not matter, therefore, whether the liquid in the reservoir is of uniform consistency or not. The only need of agitating the liquid at all, with this device, is the fact that if the heavier part of the material is permitted to rest undisturbed on the bottom of the reservoir, it will be drawn off in the immediate vicinity of the suction tube and will not flow in from other parts to fill the void thus formed, hence a portion of the heavier part of the liquid will remain while the lighter part will be pumped out. Any device that prevents the sediment from lying still on the bottom of the reservoir answers the purpose. When a barrel is used for the reservoir this is accomplished by discharging two small streams from the pump into the barrel at the bottom, and on opposite sides of the chamber, the streams passing out in opposite directions, which causes a circular motion to be set up in the bottom of the mass. This secures the needed circulation of the materials, and with a minimum expenditure of force, for the movement is all in one direction. In case the reservoir is not circular in horizontal section, a mechanical device may be needed to keep the lower stratum of the materials in motion, but a very slight agitation will answer the purpose.

The apparatus applied to a barrel, as the reservoir, appears in the accompanying sectional drawing. (Fig. 46.) In this case the pump happened to be of the style known as the "Nixon Climax," but any of the spray pumps commonly used upon a barrel can be adapted to it with slight modification.

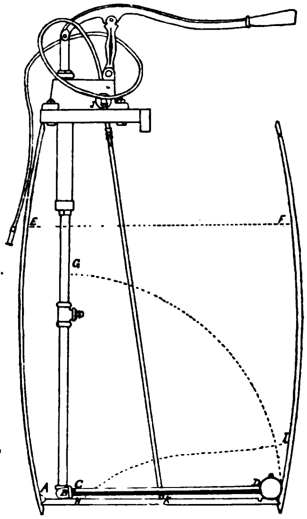

FIG. 46.—Showing spraying pump as used on a barrel.

Instead of the rubber suction-tube commonly used in the Nixon pump, we substitute a ½ inch gas pipe, of such a length that when a street elbow is attached to its lower end, the elbow just reaches the bottom of the barrel at A.*

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* The tee near the center of this pipe is used for the kerosene spraying attachment described further on.

To the outside thread of this street elbow a three-way elbow is attached, but is not screwed on so tightly as to prevent it from moving freely on the thread. Into this three-way elbow the tube C D is now screwed, in such a way that when the tube is laid down horizontally, as shown in the drawing, the remaining opening of the elbow faces downward. A three-eighths inch bushing is next screwed into this opening, over which is wired two thicknesses of strainer cloth. The tube C D is of heavy sheet copper soldered at C to a very short section of iron pipe having a thread cut on it, and at D it extends between two short cylinders of light copper, which are soldered to it on either side and which answer as a float. For a 50 gallon barrel these cylinders should be 2¼ inches in diameter and 1¼ inches in length. Each should have a neck soldered in, as shown, to receive a cork, so that they may be ballasted to float at the right height. The lower portion of the tube C. D.; (as it lies in the picture) is cut away and the opening thus formed is covered with brass strainer cloth, soldered on.

Let us now suppose the reservoir to be filled with Bordeaux mixture up to the dotted line E–F. The float at D will rise, bringing the right end of the tube C D with it, (the other end moving in the elbow joint at B) until the float reaches the point G. If now the pump is started the liquid in the reservoir will pass through the wire-cloth-covered side of the tube C D as fast as it is withdrawn by the pump, and it will flow into this tube throughout its whole length simultaneously, for while the suction would be first exerted upon the liquid in the tube at its lower end, the withdrawal of a part of the liquid at this point tends to produce a vacuum which the weight of the liquid in the tube above will tend to fill at once, and this will cause a movement of the outside liquid through the whole length of the wire cloth. It matters not if the liquid becomes more dense in the bottom of the reservoir than at the top because the suction, being first exerted at the bottom, will draw in a portion of the dense part which will be mingled with the lighter part above in passing through the pump. If, however, the liquid were permitted to remain wholly stationary, a mass of sediment would ere long settle to the bottom, having a surface line something like that represented by the dotted line H I; i. e., it would be lowest at the lower end of the suction tube and highest farthest away from it. To prevent this, a ¼ inch gas pipe extends from the bottom of the air-chamber of the pump at J, to the bottom of the barrel, where it ends in a "tee," into which are screwed two sections of pipe of the same size, and of sufficient length to reach the outside of the barrel on opposite sides (see Fig. 47), where each ends in an elbow, and the orifice of the two elbows extends in opposite directions. Into each of these elbows is screwed a plug

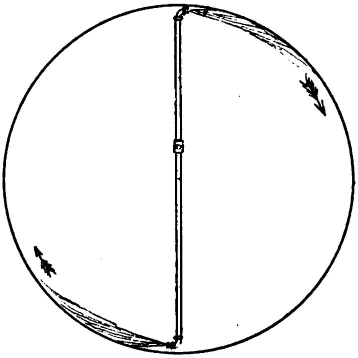

FIG. 47.—Showing arrangement of pipes at bottom of barrel to prevent accumulation of sediment.

having a minute hole drilled through it lengthwise. These plugs, and also the street elbow mentioned above, are preferably made of brass, but if the pump is always cleaned after using by pumping clean water through it, the parts made of iron will give very little trouble. The holes in the plugs should be drilled from the inner end and should be 1-8 inch in diameter until nearly through, but should terminate about 1-32 inch in diameter. The liquid, being forced through these orifices against the circumference of the barrel by the action of the pump will gradually set up a revolving movement in the contents of the reservoir, near the bottom, which will prevent the accumulation of sediment in any one place. Of course more power is required on the pump handle to force the liquid out through three openings than through the spraying nozzle alone, but the additional power required is not great and no mixing device can be operated without the application of some power.

When the spraying liquid is properly strained before being placed in the reservoir, these small orifices in the plugs will not trouble by clogging. The pump should not, however, be left filled with the liquid, and before starting, these orifices should be examined to make sure that they are open.

As the level of the liquid in the reservoir lowers, the float at the right end of the tube C D will lower with it. The reservoir may be filled to a point a little above the float when the tube is standing erect, without preventing the uniform distribution of the liquid. In case a pump of some other design than the one here illustrated is used, the return tube J K might need to be attached in a different manner. It could be attached where the hose connects with the pump by placing a tee next to the pump and attaching the hose to this, connecting the return tube with the side opening of the tee.

Experiments made with this apparatus have shown it to spray the Bordeaux mixture with approximate uniformity, even when it had been allowed to settle over night and the pump was started the next morning without mixing the liquid. Fig. 48 shows three samples of Bordeaux mixture as delivered by the pump, one of which was taken at the beginning of a spraying, the second at about the middle, and the third at the extreme end. The reservoir contained 15 gallons of the mixture that had been made up the day before, and had been allowed to settle 1 1-2 hours immediately before starting the pump, at which time, a sample of the liquid dipped from the top of the reservoir appeared perfectly clear. The pump was started without mixing the contents of the reservoir in the least. As appears from the illustration, the amount of sediment was practically the same in the three samples. The samples were not always quite so nearly uniform as this.

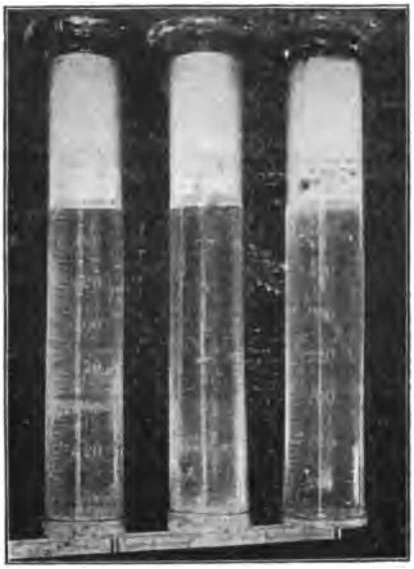

FIG. 48.—Showing samples of Bordeaux mixture taken at the beginning, middle and end of a spraying. The white portion at the bottom of the cylinders is the sediment; the cylinders were filled up to the cord tied about each one near the top.

Fig. 49 shows the result of using the apparatus on a square tank having glass sides which permitted a view of the interior. In this case a mechanical agitator consisting of a small frame made of lath, which rested horizontally at the bottom of the reservoir, was connected by a vertical shaft with the casting that supports the pump handle. Thus a short reciprocating movement was communicated. At the beginning, the Bordeaux mixture had been allowed to settle for several hours, and presented the appearance shown in the illustration. The pump was started without mixing the contents of the reservoir, and samples of the mixture as delivered by the pump were taken at intervals.

The first sample was taken when the pump was started, and the last just as the reservoir was being emptied. The mixture pumped out was then replaced in the tank, and after it had settled during several hours, the tank, with the cylinders, was photographed. The amount of sediment in the cylinders shows that the distribution of the mixture was practically uniform. (Unfortunately the illustration does not distinctly show the line separating the sediment from the clear liquid above, but by close observation it may be seen.)

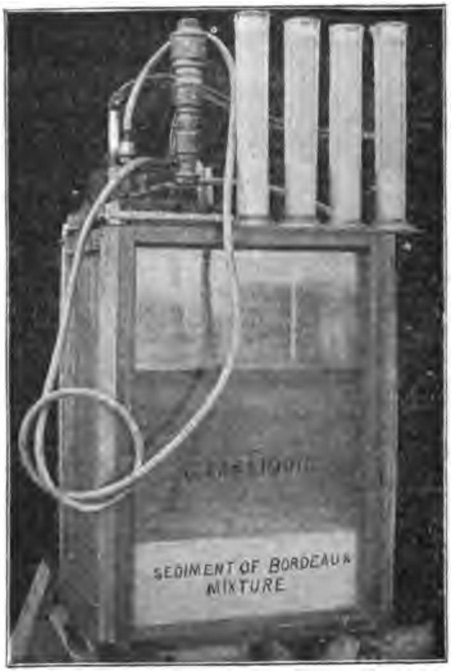

FIG. 49.—Showing spraying pump on rectangular reservoir. The glass cylinders contain samples of the Bordeaux mixture taken at different times during the emptying of the reservoir by means of the pump. As appears from the amount of sediment in the cylinders, the mixture as pumped was practically uniform.

One precaution needs to be emphasized in using the Bordeaux mixture with any spraying device, viz., the mixture should always be strained through a coarse cloth before attempting to spray it. It should be prepared when possible in a distinct vessel from the reservoir from which it is to be pumped, and then strained into the reservoir. A piece of burlap answers well for a strainer. Without this care, it is almost sure to give trouble by clogging the strainer at the entrance to the suction tube, or by clogging the nozzle.

Attachment for spraying kerosene and water.— The chief difficulty heretofore experienced in spraying kerosene and water has been in securing a uniform proportion of kerosene. Unless the surface of the two liquids is maintained practically on a level, the amount of kerosene sprayed with a given bulk of water may vary greatly. In the attachment here described, this trouble is avoided by permitting the reservoir containing the kerosene to float in the water reservoir.

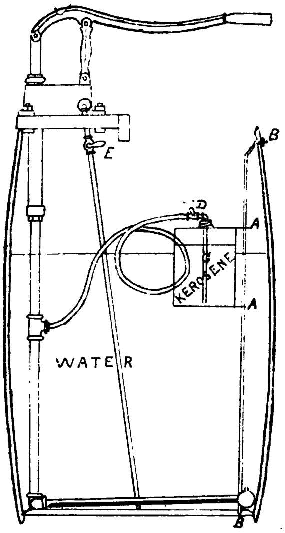

FIG. 50.—Showing spraying pump with a simple attachment for spraying kerosene with water.

In Fig. 50, the small chamber marked "kerosene" is a light tin can, holding a gallon or more, preferably of large diameter in proportion to its height. To the top and bottom of this can (at AA) is soldered a strip of heavy tin that extends out a short distance from the can, and has a 5-16 inch hole through it near its outer end. Through these holes a ¼ inch iron rod B B passes. The lower end of this rod rests in a little socket in the bottom of the barrel, and the upper end passes through the side of the barrel and is secured by a nut. If water is placed in the barrel, this can will float and will rise or fall on the rod, according to the level of the water. If kerosene is placed in the can, the latter settles into the water to a distance dependent upon the relative specific gravity of the can, with the kerosene in it, and of the water. The kerosene is lighter, bulk for bulk, than the water, but the metal of the can and the attachments connected with it are heavier, so that the level of the kerosene in the can does not vary much from that of the water, regardless of the comparative amounts of the two liquids. As the kerosene is pumped out of the can the latter rises, so that the height of the can above the water shows approximately the amount of kerosene it contains at any time.

The neck of the can is closed with a screw cap, through which passes a slender tube C which reaches to near the bottom of the can, and has an elbow at its upper end, to which is attached a stopcock D which is used to regulate the proportion of kerosene that is sprayed. This tube may be of tin, but it will be much more substantial if made of brass; three-sixteenths inch in diameter is sufficient. It should be soldered to the cap at such a point that when the latter is screwed down, the stopcock will extend toward the suction tube of the pump, and a small hole should be punched through the cap at one side of the tube to admit air to the can. The stopcock is connected with the suction tube of the pump by a rubber tube as shown. This tube should have a loop in it, as indicated, to permit the rise and fall of the can.

In operating the pump, the stopcock at E is closed, and the one at D is partially opened. To test the proportion of kerosene that is being pumped with the water, spray the mixture into a tall, straight-walled bottle, after having pumped a few strokes, and stand the bottle on a level place for ten minutes, to permit the kerosene to rise. About one part of kerosene to 10 or 12 of water is satisfactory in most cases. Having found the adjustment of the stopcock that delivered this proportion of kerosene, a mark may be made on the cock that will enable it to be adjusted to the same point again, but it is well to test it anew after the kerosene attachment has been removed and replaced, as indices attached to stopcocks that are used at intervals are generally unreliable. Experiments made with this attachment showed that the proportion of kerosene delivered was sufficiently near uniform for all practical purposes.

COLD VS. WARM WATER FOR PLANTS.

F. CRANEFIELD.

Several tests have been made during the year to determine the comparative influence of warm and cold water on plant growth. Most of the work has been carried on under glass but under conditions approaching to those out of doors.

Two crops of tomatoes and a crop of radishes were grown in our "garden house," a glass-roofed structure without benches, 22x75 ft., running north and south. The soil consists of 14 inches of well manured loam underlaid with several feet of gravelly clay.

For the first crop of tomatoes seed was sown July 15th in flats in an adjoining greenhouse and the [plants were pricked off when of proper size and later, were potted in 4 inch pots. On Sept. 15, twenty-seven plants were set in rows east and west. The plants were quite uniform in size, averaging 10.1 inches in height. All were trained to a single stem and were tied loosely to a soft string fastened to the plant near the ground and to a horizontal wire above. When a majority of the plants had grown to a height of 5½ feet, the terminal shoots of all were pinched to stop growth.

All blossoms were artificially pollinated and very few of them failed to set fruit; not more blossoms failed on one row than on another. The temperature of the house was kept as nearly 60° Fahr. at night and 70° in the daytime as possible. The plants were watered as often as needed, which was usually once a week. From two to three gallons were applied to each plant. The earth was drawn away from each plant and ridged so as to form a cup. No water was applied to the ground between the rows at any time.

All temperatures are recorded in degrees Fahrenheit, except as otherwise noted.

From Sept. 25th to the close of the experiment the plants were watered as follows:

Two rows with water at 32° to 36°.
Two rows with water at 60°.
Two rows with water at 90°.

The plants received no water except as above noted. The ice used in cooling the water was taken from the same source as the water.

For convenience the plants in this and following experiments will be referred to as follows, 32°, 60° and 90°. On Nov. 25th the height of the plants was as follows:

32° averaged 5.41 ft.
60° averaged 5.35 ft.
90° averaged 5.28 ft.

Showing a slightly greater gain in height in favor of the 32° lot.

A record was taken at several different times of the temperature of the soil both before watering and at intervals of 15 minutes for several hours afterward. A thermometer was inserted in the soil near the base of a plant and from 2 to 6 inches below the surface. The diagram (Fig. 51) shows the variations of temperature of the soil about one plant of each lot at 4 inches below the surface. The figures at the left denote degrees Centigrade; those at the top denote hours.

It will be noticed that the soil of the 32° lot dropped in temperature suddenly 8 degrees, and after 12 hours had not regained its original temperature. That of the 60° lot was but slightly affected, while that of the 90° lot rose at once over 3 degrees Centigrade but soon fell to a trifle below the original temperature.

Fig. 52 is a graphic record of the soil temperatures taken in a similar manner Nov. 22nd.

The first fruits that ripened were on the 32° lot; these were followed closely by other ripe fruits on the 60° lot. Six pickings were made — the first Dec. 7th, and the last Jan. 15th. In the following table is given the total yield of each lot, the total number of fruits, the average weight of the fruits and the weight of the plants. In the latter case the great bulk necessitated employing avoirdupois weight:

Table giving number of fruits, weight of fruits, height of plants, etc.

No. of lot.	Total No. fruits.	Total wt. of fruits.	Average wt. of fruits.	Weight of plants.	Height of plants.
	Grammes.	Grammes.	Grammes.	Lbs.	In feet.
32°	303	21,511.0	70.00	45.26	5.55
60°	300	21,014.0	70.00	41.12	5.42
90°	281	19.187.0	68.3	39.27	5.31

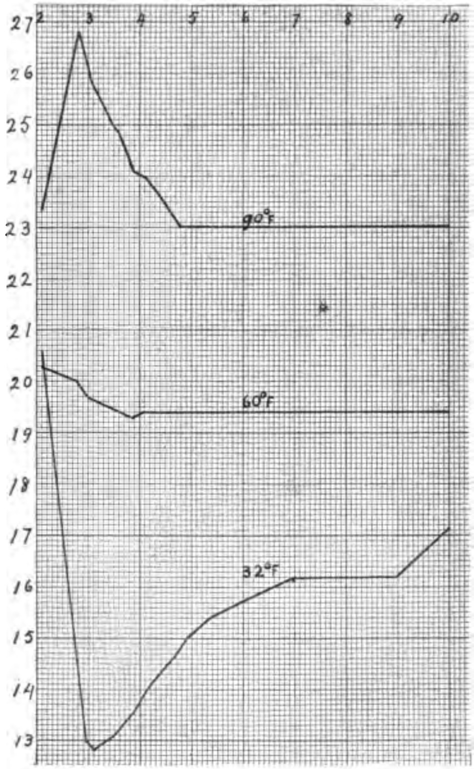

FIG. 51.—Showing variations in temperature of the soil four inches below the surface after watering with water at the temperature indicated on the cut.

From the above table it is seen that the plants of the 32° lot bore the largest number of fruits and also produced the greatest weight of plants and the plants attained the greatest height. There was also a gain in earlinesss in favor of the 32° lot as shown by the following table in which is given the number and weight of fruits gathered from the different lots in the first three pickings:

Table giving number and weight of fruits in first three pickings.

No. of lot.	No. of fruits.	Weight of fruits.
	Grammes.	Grammes.
32°	45	3,759.0
60°	50	3,318.0
90°	34	2,228.8

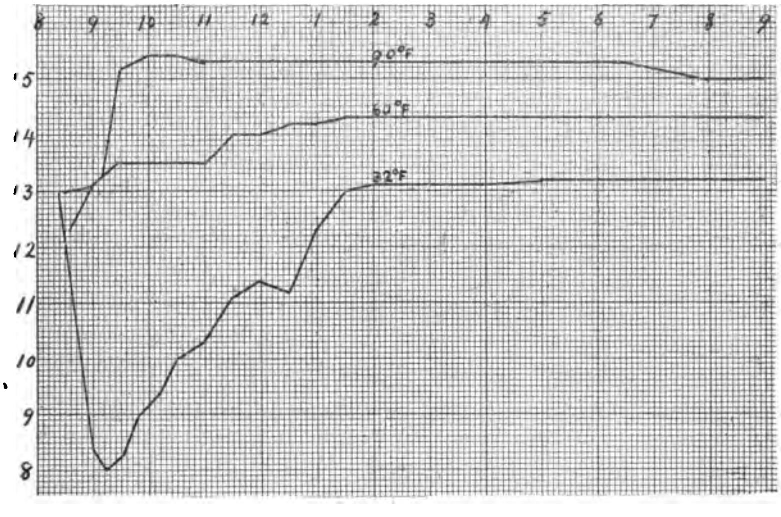

FIG. 52.—Graphic record of variations of soil temperatures at four inches below the surface about one plant of each lot, observed Nov. 22d.

Second trial with tomatoes.—A second trial was made during the winter and spring of 1898 under the same conditions as the first trial. The plants for this experiment were grown from seeds saved from the fruits of the first crop. That is, the plants designed to be watered with water at 32° were grown from seeds saved from plants so watered in the first experiment, etc.

In this trial only 20 plants were grown. The plants were set as in the first trial in rows east and west but in this case but four plants were set in a row and the rows were four feet apart. The plants averaged 9.9 inches in height when planted. Ten plants were watered with water at 32° five with water at 70° and five with water at 100°.

In this experiment the temperature of the greenhouse was kept at about 70° at night and 80° in the day-time.

The blossoms were not artificially pollinated. A record was kept of the number that failed to set fruit in each lot as follows: 32° 211; 70° 78; 100° 119.

In the following table is given the total number and weight of the fruits which ripened on the different lots, with the average weight of the fruits and the weight of plants.

Table giving number of fruits, weight of fruits, etc., in different lots.

No. of lot.	No. of fruits.	Total weight of fruits.	Average weight of fruits.	Average weight per plant.	Weight of plants.
		Grammes.	Grammes.	Grammes.	Lbs.
32°....................	92	11,757.5	127.7	....	21.5
32°....................	108	10,601.0	98.1	2,235.8	18.5
70°....................	95	10,042.5	143.4	2,008.5	18
100°....................	102	11,872.5	116.3	2,374 5	19

In this case the 100° lot yielded the largest amount of fruit and the 32° lot was next in order while the 70° lot yielded the least; but the difference is so slight that the results may be considered duplicates.

RADISHES.

A crop of radishes was grown at the same time as the first crop of tomatoes and in the same house.

Three plats of four rows each were planted; the rows were one foot apart. Seed of the Bertram Forcing variety was sifted so as to retain only the largest seeds and one thousand seeds were sown in each plat in drills ½ inch deep. After the plants appeared all were thinned so as to stand about 2 inches apart in the rows. One plat was watered with water at 32°, one with water at 45°, and one with water at 70°. The water was applied with a sprinkling can using a fine rose. The progress of germination in the different plats is indicated by the following countings:

Table showing the progress of germination in the different lots.

No. of Plat.	1st count.	2d count.	3d count.
32°..	283	607	764
45°..	487	689	873
70°..	473	649	790

The above data indicate that the germination of the seeds in the 32° lot may have been retarded by the low temperature of the water used.

When the roots were ¾ inch in diameter, the plants were pulled and weighed entire, after which they were topped and the roots weighed separately.

In the table below is given the total weight of the crop and the weight of the roots, with the average weight of each lot.

Table giving number and weight of radishes, etc.

No. of plat.	No. of radishes.	Total wt.	Total wt. of roots.	Average weight.	Average wt. of roots.
		Grammes.	Grammes.	Grammes.	Grammes.
32°,	205	1124.0	532.0	5.5	2.6
45°]	259	1491.0	697.0	5.75	2.69
70°	279	1688.5	817.0	6.05	2.93

This shows a difference of about ½ gram between the average weight of the 32° and the 70 with a difference of 1-3 gramme in the average weight of the roots.

Other trials in the greenhouse.— Several trials were conducted with vegetables and flowering plants in the Station greenhouse — an even-span house 22x75 ft., running north and south, with raised benches

Beans. — A section of 16 feet of a central bench was divided by means of board cross partitions into 8 beds each 2x4 feet and 4½ inches deep. All were filled with thoroughly mixed soil.

In each bed was planted 14 plants of Ne Plus Ultra beans, grown from selected seed previously planted in a box of sand. The beds were watered with water at 32°, 40°, 70° and 100° respectively. An equal quantity of water was given to the different beds at each watering. The pods were picked when about 4 inches long. Below is given the total length of pods, total weight of pods and the weight of the plants; also the weight of the pods in the first three pickings.

As the beds were thoroughly drained and the soil was porous, no bad results followed from applying an equal quantity of water at each watering. The plants were uniform and vigorous and all seemed to require an equal quantity.

Table giving weight of pods, length of pods, weight of plants, etc.

No. of lots (28 plants in each).	Total length of pods.	Total weight of pods.	Weight of plants.	Weight of pods first three pickings.
	Inches.	Grammes.	Grammes.	Grammes.
32°	1,062.25	703.7	650.0	318.5
40°	1,117.54	711.7	606.5	347.1
70°	971.5	596.2	539.5	298.6
100°	859.6	556.4	564.9	270.0

The above table shows that the two lots which received the coldest water produced the greatest weight of pods, also the greatest length of pods and the heaviest plants. In the right hand column is given the weight of pods from the different lots in the first three pickings, showing an advantage in earliness for the 40° lot and the 32° lot.

Fig. 53 shows two of the beds at the time of the firs picking, from which it appears that the plants were practically uniform in size.

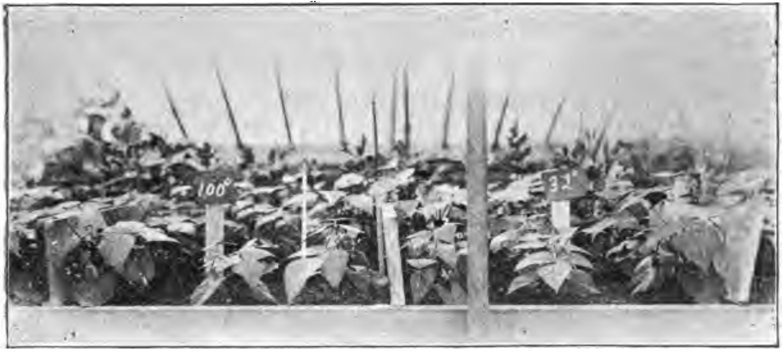

FIG. 53.—Showing plants of 32° lot and 100° lot at time of first picking.

Tomato plants in pots.—One hundred tomato plants which were grown from seed saved from 2nd generation of cold and warm water plants were potted, divided into 4 lots and watered as in the previous experiment, viz.: with water at 32°, 40°, 70°, and 100° respectively. All of the plants were measured from time to time and at two months from the date of sowing seed 15 plants of each lot were cut off at the cotyledons and weighed, the remainder being saved for another experiment. The data are given in the following table:

Table giving average height of plants at different periods, also average weight of plants.

No. of lot.	Av. height at 1st measurement.	Av. height at 2d measurement.	Av. height at 3d measurement.	Av. weight of 15 plants.
	Inches.	Inches.	Inches.	Grammes.
32°	3.63	5.65	12.65	55.9
40°	4.39	6.12	13.8	58.7
70°	4.28	6.7	14.7	65.3
100°	3.79	5.9	13.7	58.0

No influence appears here that can be ascribed to the difference in temperature of the water used. The following table gives a record of the soil temperatures as indicated by Centigrade thermometers plunged in the soil near the stem of one plant of each lot.

Table giving record of soil temperatures.

No. of lot.	Before watering.	After 1 hour.	After 2 hours.	After 3 hours.
32°	20.2° C.	17.8° C.	19.6° C.	24.2° C.
40°	20.8	19.2	20.6	24.2
70°	20.0	20.8	21.4	24.2
100°	20.4	24.0	23.6	24.2

From the above it appears that the influence of the temperature of the water used in watering was not apparent after the lapse of three hours.

Tomatoes on raised bench.—The 20 plants noted as reserved in above experiment, were planted in 4 beds each 2x4 ft. — five plants in a bed. The plants were from 6 inch pots and were set in 8 inches of soil. They were trained to single stems and all were pinched on the same date. The yield of fruit and the weight of the plants are given below. The different lots were watered as in the previous enperiment.

Table giving total weight of fruits, and total weight of plants.

No. of lot.	Total weight of fruits.	Total weight of plants.
	Grammes.	Grammes.
32°	1,379.0	196
40°	1,130.0	198
70°	1,188.5	182
100°	1,408.8	161

In this case the 32° lot yielded more than the 70° lot, but less than the 100° lot.

Lettuce.—On March 31st, ninety-six plants of Grand Rapids lettuce were set in 4 beds each 2x4 feet, 24 plants in a bed and watered as in the preceding experiment.

April 28th all the plants were cut and weighed with the following results:

32°	786.4 grammes	70°	695.3 grammes
40°	783.1 grammes	100°	768.5 grammes

This shows a slight gain in favor of the 32° lot, but the weights vary so little that they may be taken as duplicates.

Beans.—Twenty-four uniform plants of the Ne Plus Ultra variety were planted in 4 boxes, 6 plants in each box. In this case water of the following temperatures was used, 32°, 40°, 70° and 110°.

The beans were allowed to fully mature and when air dry were weighed with the following results:

32°	24.3 grammes	70°	18.5 grammes
40°	20.7 grammes	110°	16.33 grammes

From this it would seem that the warmer water was unfavorable to the growth of beans.

Radishes.—Forty-eight uniform radish plants were planted in boxes, 12 plants in a box, and watered as in the above experiment. The radishes were pulled and weighed when of marketable size, after which they were topped and the roots were weighed separately. The following table gives the results in grammes:

32°.		40°.		70°.		110°.	
Entire weight.	Weight of roots.	Entire weight.	Weight of roots.	Entire weight.	Weight of roots.	Entire weight.	Weight of roots.
102.0	58.8	82.5	49.2	84.0	49.5	84.1	48.6

There is in this as in the preceding trial a marked difference between the warmest and the coldest-watered lots. Water at 110° is probably too warm for radishes, while that at 32° appears to be more favorable than that of a higher temperature.

Coleus.—The experiment with Golden Bedder coleus described in the 14th Annual Report of this Station (p. 317) was repeated during the past season. Four lots of cuttings were rooted in separate compartments on the propagating bench, in which they were placed Jan. 12th. They were watered as indicated in the table below and were potted in 3-inch pots from which they were later shifted to 6-inch pots.

May 18th, two plants from each lot were selected and weighed, after the soil had been washed from their roots, with the following results:

32°	238.5 grammes	70°	251.0 grammes
40°	216.0 grammes	100°	268.0 grammes

Showing a slight gain in favor of the 100° lot.

Later the remaining plants were cut off at the surface of the earth in the pot and weighed with results as follows:

32°	373 grammes	70°	377 grammes
40°	325 grammes	100°	371 grammes

In this case it is difficult to discover any influence due to the temperature of the water used.

Water culture.—In all the experiments so far reported it has been observed that the temperature of the soil about the roots of the plants has been but slightly affected by the varying temperatures of the water used. While an application of ice water to plants growing in 4 or 6 inches of soil would perceptibly lower the soil temperature for a time it soon regained its original temperature. In fact the variations in temperature of the soil on greenhouse benches, due to alternations between sunshine and shade, are often greater than have followed the use of water at the varying temperatures noted. In order to observe the effect on growth when the temperature of the growth medium was maintained for a considerable time above or below the normal the following trials were made.

Sixteen graduated glass cylinders each of 200 cubic centimeters capacity were filled with water and the tops covered with cheese cloth. Then sixteen beans which had been previously germinated in sawdust were placed one on each cylinder with the hypocotyls extending downward through the cloth and into the water.

The cylinders were then placed in a nearly saturated atmosphere for several days until rootlets had developed on the bean plantlets and the plumules had appeared, after which the cylinders were wrapped with cotton wadding and removed to the greenhouse. The water in the cylinders was changed daily, hydrant water being used. When the plants had attained a considerable size, Sach's nutrient solution[1] was substituted for the water and a small quantity of sulphate of iron was added. The cylinders were divided into 4 lots and the temperatures used were the same as in previous experiments, viz.: 32°, 40°, 70° and 100°. At 8:00

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* Sachs' Lectures on the Physiology of Plants, p. 284.

A. M. the temperature of the solution in all of the cylinders was 20.4° Centigrade. The solutions were replaced with others of the temperatures noted above and the time required for the different cylinders to regain their normal temperature is indicated below.

Table showing changes in temperature in cylinders and time required for each to regain its original temperature.

Time.	32° F.	40° F.	70° F.	100° F.
	Deg. C.	Deg. C.	Deg. C.	Deg. C.
8:00 A. M	20.4	20.4	20.4	20.4
9:00 A. M	9.4	11.2	20.2	30.0
10:00 A. M	12.2	12.4	19.4	25.0
11:00 A. M	18.2	18.0	19.4	21.4
1:00 P. M	22.2	19.0	20.4	21.4

It appears that the solution in the cylinders required more time to regain the original temperature than was required by the soil in the pots in the previous experiment·

The plants were weighed at intervals of 10, 30 and 70 days, the solution being lowered to a given level in all of the cylinders each time before weighing, the cylinders being weighed separately on a Torsion balance. The following table shows the gain in the different lots for the periods noted:

Table showing gain in weignt of plants in different lots in time indicated.

No. of lot.	Gain in 20 days.	Gain in 30 days.
	Grammes.	Grammes.
32°	.8.5	8.7
40°	15.5	28.7
70°	15.8	28.6
100°	14.5	25.3

In this case the coldest solution seems to have checked the growth of the plants after the first ten days but those in the 40° lot made a greater gain than those in the 100°

lot. Fig. 54 shows one cylinder from each lot near the close of the experiment; also the method of wrapping in the cylinder at as appears the right.

In addition to the above, two trials were made under outdoor conditions; one with tomatoes and one with beans and radishes.

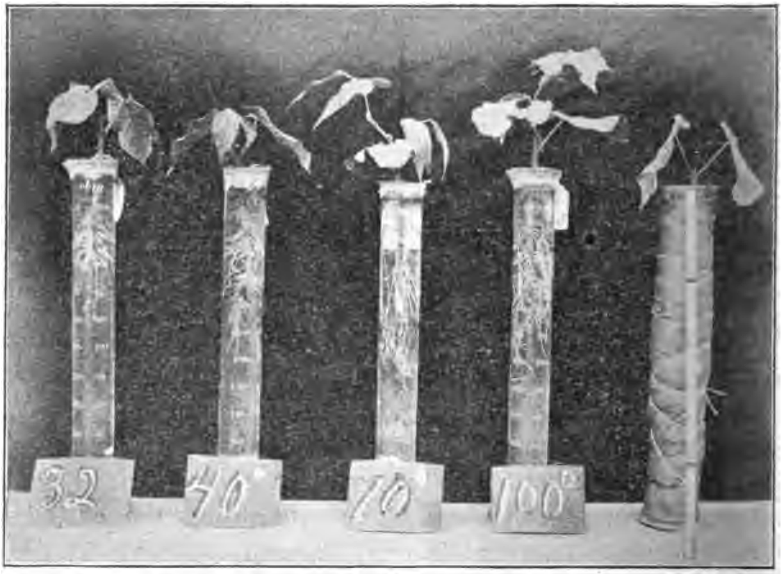

FIG. 54.—Showing sample plants grown in water at varying temperatures; also one plant, at right, showing method of wrapping.

Eighteen half-barrel tubs were sunk in the ground until the tops were level with the surface, and filled with well enriched soil. Ample provision was made for drainage. On June 6th one Dwarf Champion tomato plant was set in each tub. The plants were uniform and about 8 inches in height. The tubs were then covered with wood-pulp hay-caps as shown in Fig. 55. The plants were then divided into two lots of nine each designated as lot 1 and lot 2.

After June 21st the plants in lot 1 were watered as needed with water at 32° to 36° Fahr. The water was cooled to these temperatures by placing a large quantity of crushed ice in the tank shown in Fig. 56. The plants in lot 2 were

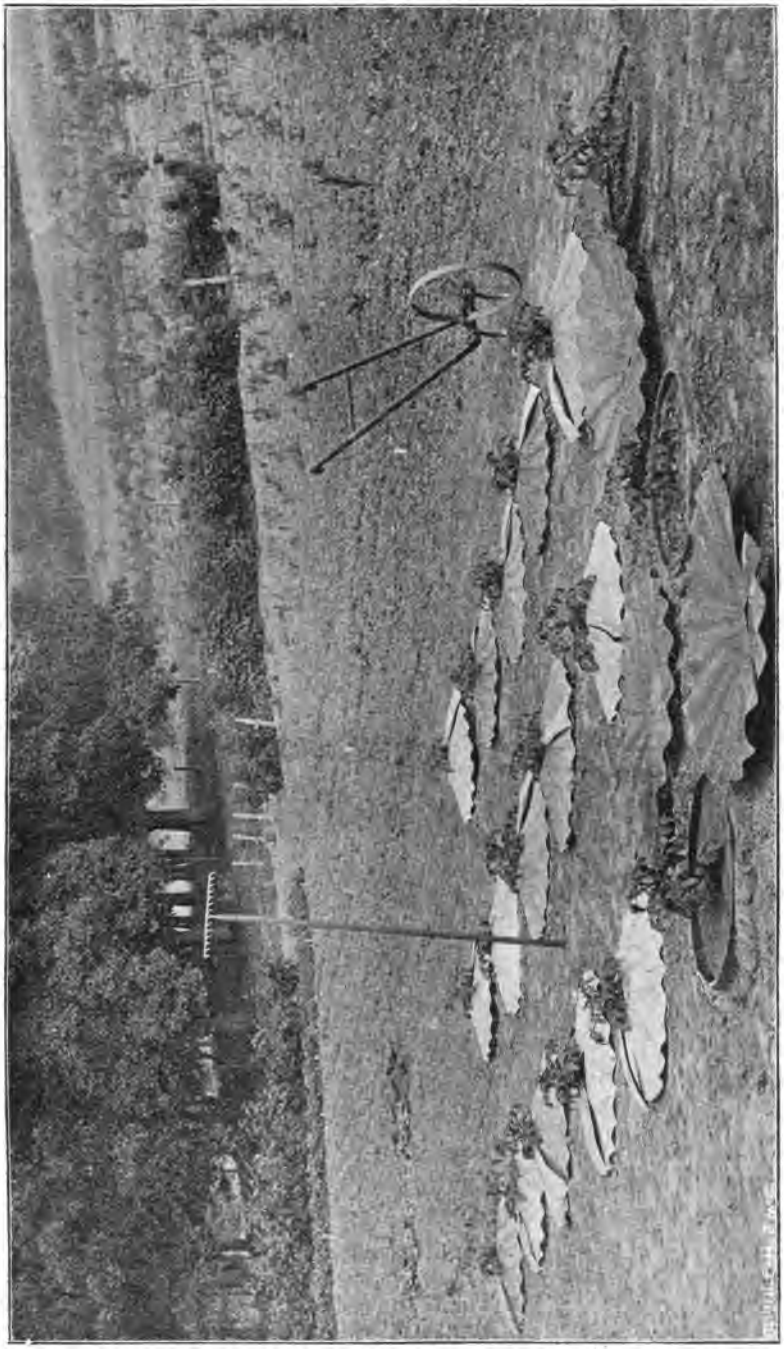

FIG. 55.—Showing tomato plat ten days after planting, and the method of planting and covering.

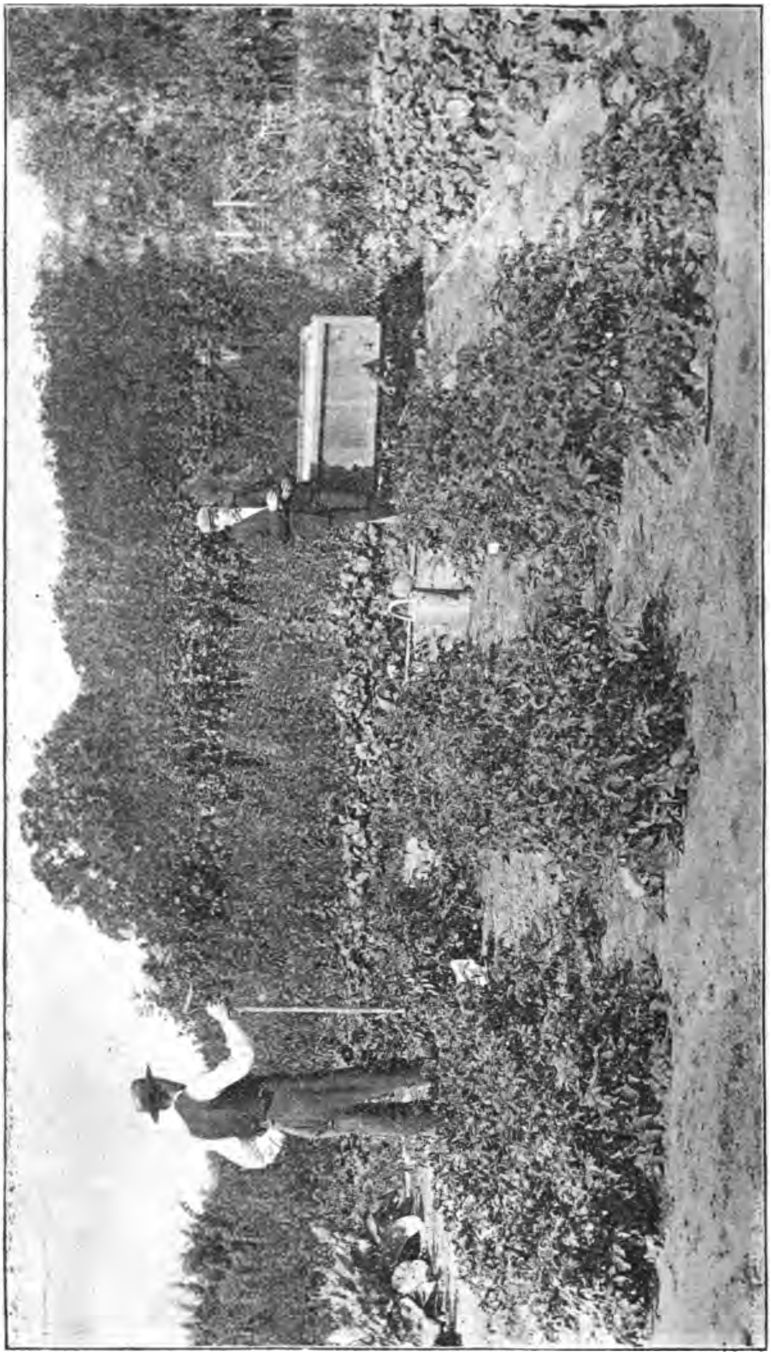

FIG. 58.—Showing tomato plat, 94 days after planting, also tank used in cooling water. Alternate plants in each row were watered with ice water, the end plant of each row, shown in the foreground, being so watered.

watered with water taken from the pipes of the irrigation system. This water varied in temperature from 60° to 80°, but was usually about 75°. In all 84 gallons of water were applied to each plant during the season.

Records of soil temperatures in the tubs watered with the colder water showed that while the temperature was lowered but 5° by the application of the cold water, 28 hours elapsed before it regained its normal temperature.

The following table shows the weight of the fruit that ripened up to Oct. 3rd from each of the lots, also the weight of the green fruit remaining on the plants at that time and the weight of the plants.

Table giving weight of fruit, weight of plants, etc.

No. of lot.	No. of ripe fruits.	Weight of ripe fruits.	No. of green fruits.	Weight of green fruits.	Weight of plants.
		Grammes.		Grammes.	Lbs.
1. (Cold water)...............	444	44,215	167	6,899	26.5
2. (Warm water).............	580	56,264	338	14,963	37
Gain in favor of lot 2.........	....	21 4-10 p ct.	....	53 8-10 p ct.	28 3 10 p ct.

As may be seen from the above the plants in lot 1 produced a greater weight of fruit and of plants than those in lot 2. The difference was less during the first half of the ripening period than during the latter half as is shown by the following table:

Table giving number and weight of fruits for first half and for latter half of the season.

FIRST HALF OF SEASON.			LATTER HALF OF SEASON.	
No. of lot.	No. of fruits.	Weight of fruits.	No. of fruits.	Weight of fruits.
		Grammes.		Grammes.
Lot 1. (Cold water)......................	179	18,402	265	25,813
Lot 2. (Warm water).....................	187	18,879	393	37,387
Gain in favor of lot 2.....................	....	2 4-10 p ct.	....	30 9-10 p ct.

The plants in lot 1 appeared as healthy and vigorous as those in lot 2 during the first half of the season, but during the latter half, when the weather had become cooler and the period of most vigorous growth had passed, the plants in lot 1 appeared unhealthy.

By using the tubs the effect of the colder water was undoubtedly intensified as the intervening wood prevented the soil in the tubs from being warmed by the surrounding warmer soil. The yield of fruit was slightly greater from the plants watered with the warmer water.

A trial with radishes and beans.—Two rows of beans of the Stringless Bush variety and three rows of the Yellow Summer Turnip radish were planted June 15th. The rows were each 50 ft. long and 18 inches apart. This plat was then divided crosswise into three equal sections and each section was inclosed with 8 inch boards sunk 6 inches into the ground. Plat 1 was irrigated during the season with ice water, plat 2 with hydrant water — the same as used in the tomato experiment above described — and plat 3 was not irrigated at all. Plats 1 and 2 were irrigated twelve times each, one hundred gallons of water being applied slowly at each irrigation. The radishes were pulled and weighed Sept. 8th with the following results:

Table giving the number and weight of radishes, etc.

No. of plat.	No. of radishes.	Total weight.	Weight of roots.
		Lbs.	Lbs.
1. Cold water	175	155.9	97.7
2. Warm water	175	142.3	88.3
3. Not irrigated	175	126.9	86.6

In this case the plants watered with ice water exceeded in weight the ones watered with warm water about 8 per cent., while those not irrigated at all weighed 18 6-10 per cent. less than those watered with ice water. It follows then, other conditions being equal, that twelve thorough waterings with ice water produced 10 6-10 per cent. greater yield than where no water was used. The rainfall during the past season was regarded as nearly or quite sufficient for the development of crops well cared for.

A trial with beans.— An equal number of bean plants were grown on each plat. The pods were allowed to ripen before being picked. The number of pods, the weight of beans and the weight of 100 beans from each plat is given below.

Table giving number of pods, weight of beans, etc.

No. of plat.	No. of pods.	Weight of beans.	Weight of 100 beans.
		Grammes.	Grammes.
1 (cold water)	763	1,361.0	50.0
2 (warm water)	772	1,381.5	46.5
3 (not irrigated)	630	982.0	49.5

The above shows a slight gain in total yield in favor of plat 2, while the beans grown on plat 1 were evidently larger than the ones grown on plat 2.

SUMMARY.

From the results of these and numerous other trials not here noted, the conclusion appears fully warrantable that the growth of ordinary field and garden crops is not affected by the temperature of any water ordinarily available for irrigation purposes.

The temperature of the soil about the roots of the plants so quickly regains its original temperature that no check to growth is likely to result.

It is concluded from the results of the out-door work that no harm can result from using for irrigation purposes water from the coldest springs or wells, for in Wisconsin the temperature of the water from these sources will not be less than 40 degrees in any case when taken from the well or spring, and by the means ordinarily employed in irrigation would be raised many degrees above this point before reaching the roots of the plants.

It is concluded from the results of the greenhouse work that for vegetable and flowering plants commonly grown under glass, well or spring water may be freely used, at any time of the year, without warming.

DESCRIPTION OF THE NEW DAIRY BARN AND STOCK-JUDGING BUILDING.

W. L. CARLYLE.

In 1896, when it had been decided that a dairy barn should be constructed at the University Farm, Dean Henry visited a number of agricultural colleges and large farms in the eastern states for the purpose of securing general ideas in relation to the desired structure. In 1897 Professor King and Superintendent Adams made an extended tour through Canada and several eastern states to secure more detailed information on the same subject. When the general plans in relation to the building were decided upon, Mr. J. T. W. Jennings, of Chicago, was chosen architect. The style of architecture adopted by Mr. Jennings is that seen in the rural buildings in certain parts of Normandy, France, which are so attractive to tourists. The interior furnishings of the barn and stables were worked out by Superintendent Adams and the writer.

Acknowledgment is due to Mr. H. B. Gurler, of DeKalb, Ill., one of America's most advanced dairymen, for suggestions in regard to this part of the structure, especially in reference to the cow stalls, which were modified from those in his own modern stable. We were also aided in working out the details of the stalls in the cow stable by Mr. Geo. K. Rix, of the Barbee Wire and Iron Works, Chicago, and in the stall details in the young-stock stable by Mr. John T. King, of Madison, Wis.

In examining the illustrations and reviewing the description here given, the reader is asked to bear in mind that the structure is an agricultural college building; where everything is arranged for the housing of a herd of cows for instructional and investigational purposes and in addition, with accommodations for hundreds of students when occupied in the work of judging live stock.

The building is a frame structure (frontispiece and Figs. 57 and 58), consisting of the barn proper, 86 feet long by 50 feet wide, with two wings each 70 feet long, projecting at right angles from each end of the main building. A large classroom is conveniently located between the two wings (Fig. 58). It is well lighted from the roof as well as from the gable. This room is 70x40 feet, provided with tan-bark floor and seats along one side of the room. It is heated by coils of steam pipe from the boiler in the basement.

The wings are two stories high, while the main building is three stories with the working floor in the third story. The trestle to the entrance of the third floor is shown in Fig. 57. It is constructed of steel, requiring six spans to cover the distance from the embankment to the building. The grade is a moderate one, being only 7 feet to 100. All the material for filling the silo, the hay bays and the straw for bedding, housed over the stables, is thus brought directly to the top floor of the barn from which it is transferred with very little work to the stables below. The grain required for feeding the stock is also taken into the building on this floor and emptied through trap doors in the floor into the feed bins on the second floor and from thence is drawn through spouts to the feed room on the main floor. A wagon scale is located on the top floor at the entrance doors where everything may be weighed. On this floor is located the ensilage and feed cutter, the cut fodder falling into the silo from the top instead of having to be elevated by carriers. The feed grinder is placed on this floor so that feed may be ground for the stock before passing into the bins below. The motive power for machinery is a 10 H. P. electric motor placed on a small truck which runs on an iron track so that it may be shifted at a moment's notice from one side of the barn to the other. The car is provided with clamps which grip the rails so that it can be held in place at any point desired. By this arrangement

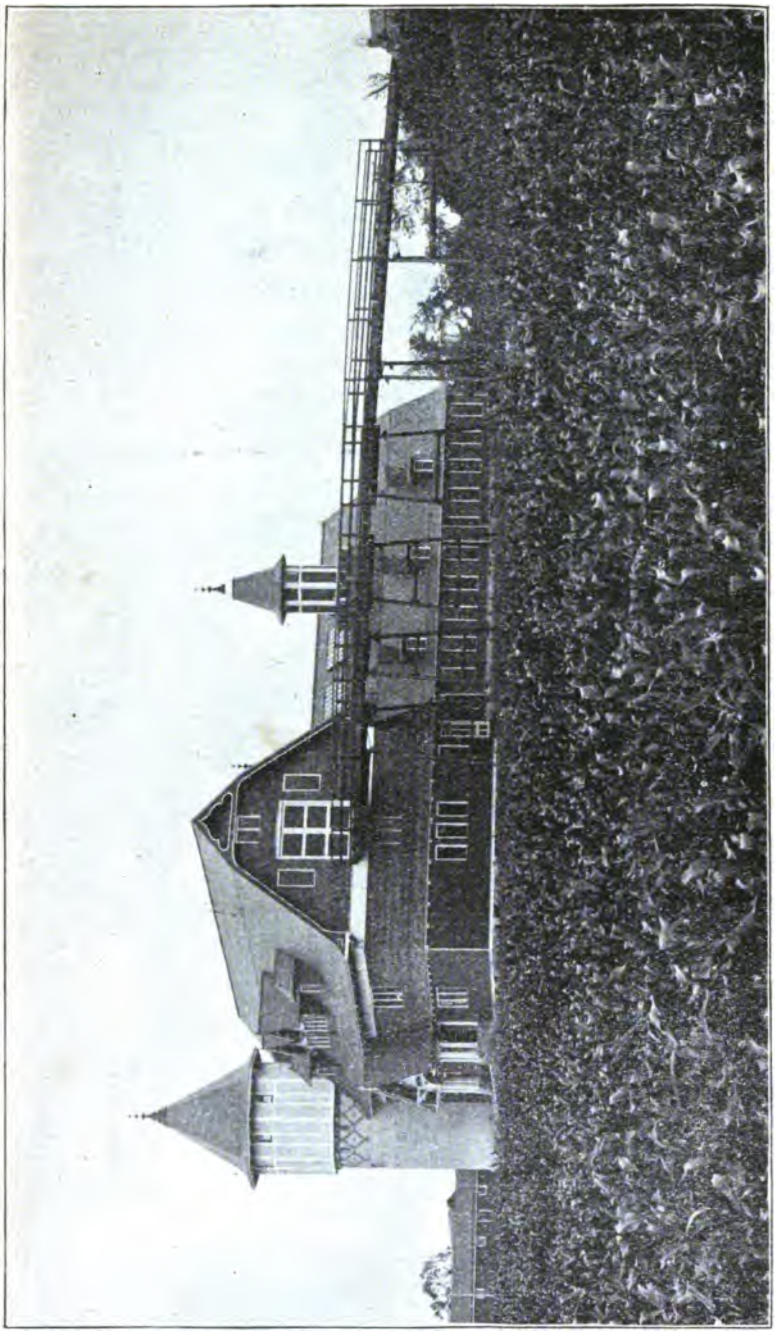

FIG. 57.—View of Dairy Barn and Stock-Judging Building from the West.

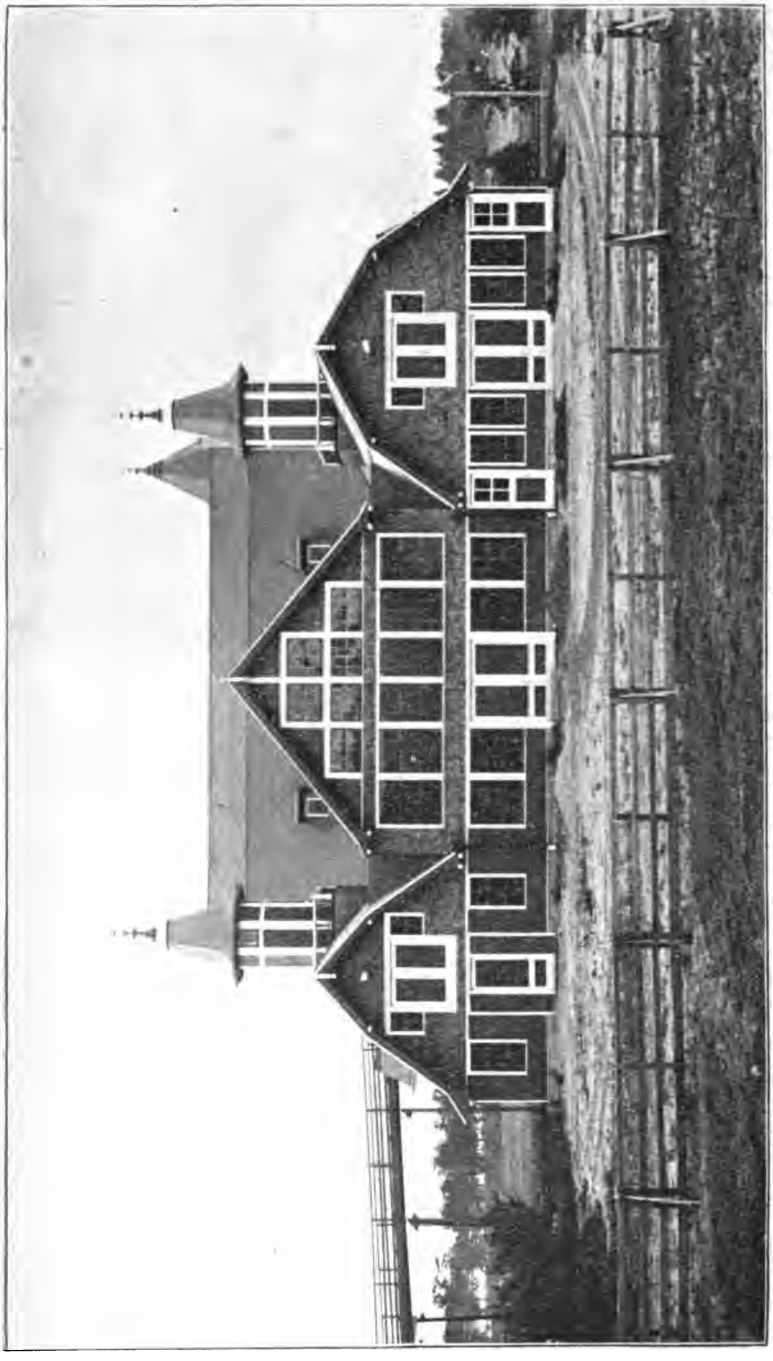

FIG. 53.—View of Dairy and Stock-Judging Building from the South.

all the power is used for the work in hand, nothing being lost by transmission through an elaborate system of line-shafts and belting. This upper floor is large enough to admit a team with a load of hay on an ordinary wagon being readily turned after driving in if it be desired. The plan of this floor is shown in Fig. 60.

Second floor.— The second floor plan is shown in Fig. 61. Apart from the portion devoted to hay bays, it consists mainly in a large storage room for cut fodders and in grain bins. Passages lead from each end of this floor into the second story of the stables where bedding is stored for the cattle beneath.

Main floor.—The plan of the main floor is seen in Fig. 59, showing the location of the office and the herdsman's room at the left of the entrance, while the hospital or lying-in stalls, an important feature in any stock barn, are found on the right. A stairway leads to the basement, and also one to the second story. A little farther to the left is a stock scale. The closet, bath and wash-room is found on this floor.

The milk room is not large, but very complete. It has a tile floor with marble baseboard and is lined inside with steel sheeting heavily coated with white porcelain paint. This room contains a small cream separator, driven by a 1 H. P. electric motor. These machines were both nickel-plated by their manufacturers, free of cost to us. To the right of the milk room is the feed room where the different grain feeds may be drawn from the bins above.

Cow stable. — The cow stable is located in the left wing of the barn. This wing is 70 feet long and 40 feet wide. It is lined inside with corrugated galvanized iron sheeting, insuring a wall and ceiling surface almost perfect from a sanitary point of view. They can be washed every day if necessary with a hose and scrub brush and not remain damp.

Floors.—The floors of the stables in both wings are made of Portland cement and crushed granite, with a slightly sloping surface leading all water used in washing or scrub-

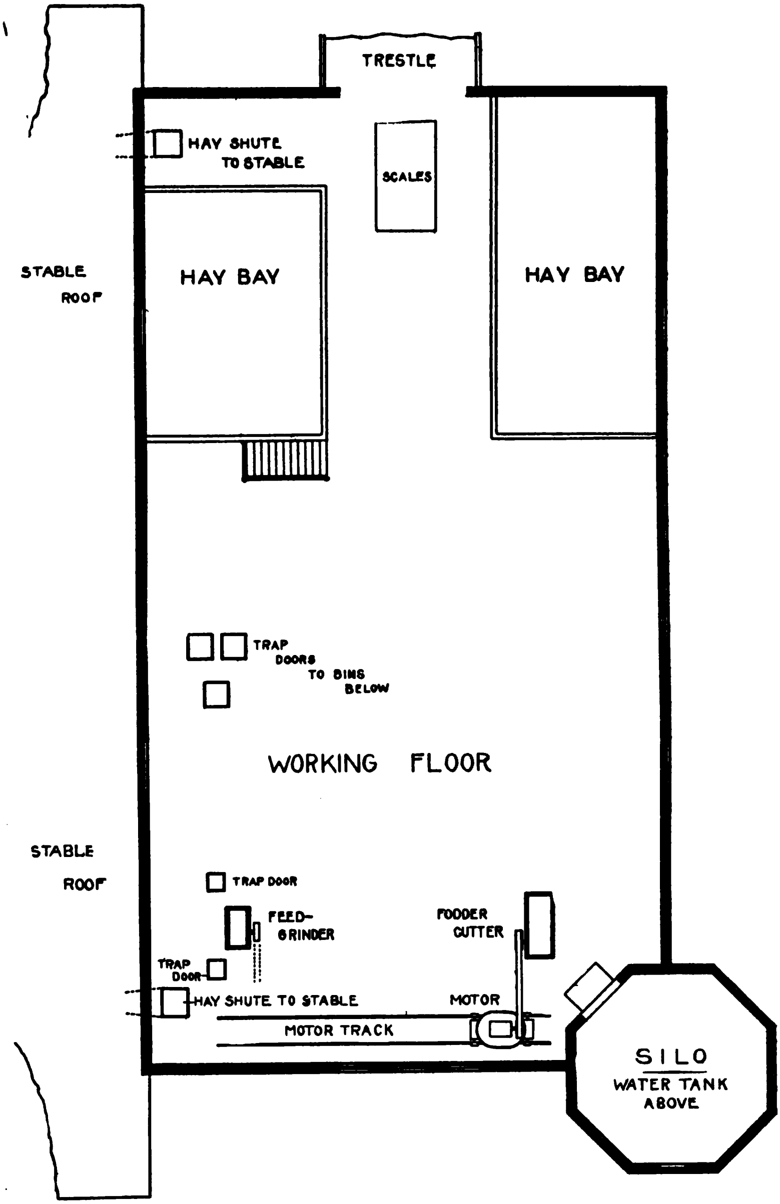

FIG. 60.—Third floor of barn showing location of feed-grinder, fodder-cutter, scales, etc.

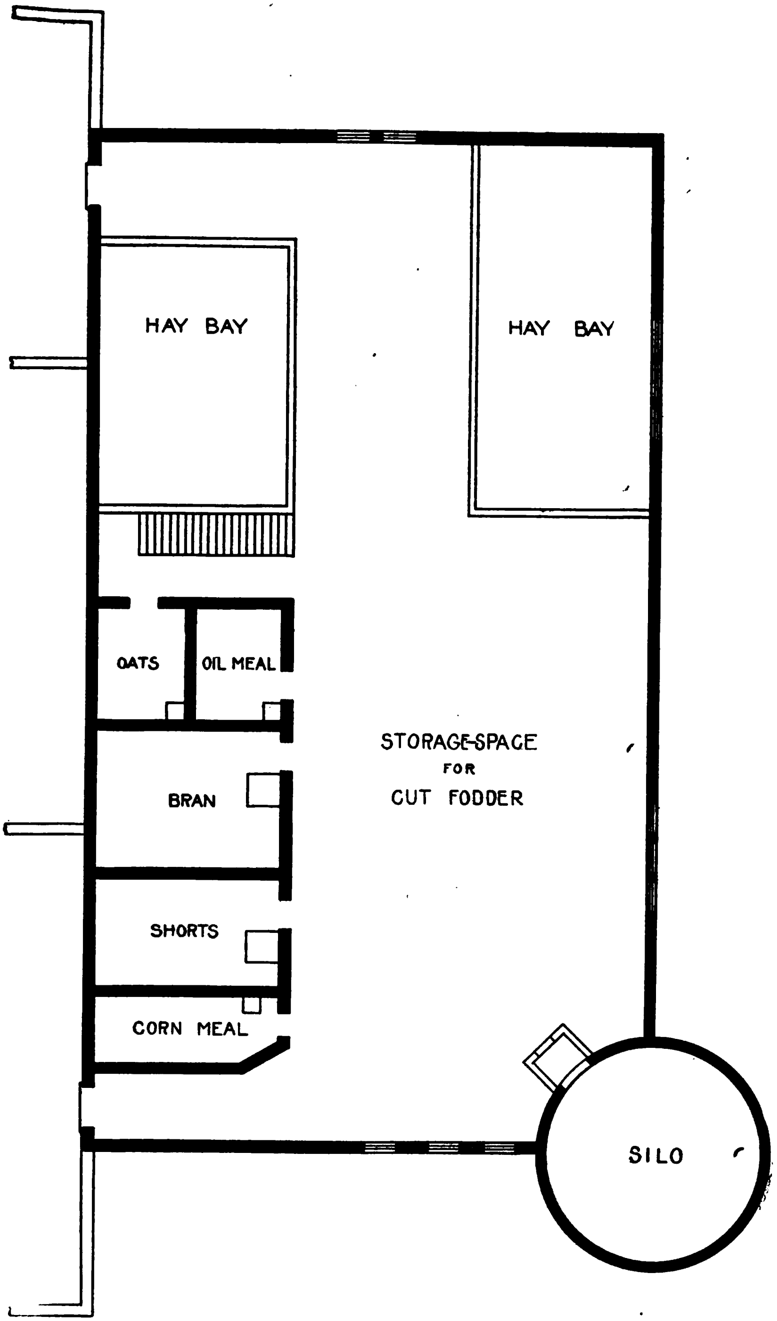

FIG. 61.—Second floor of barn, showing grain bins, etc.

bing to the sewer drains. The manure gutters behind the cows are sixteen inches wide with the bottom sloping ¾ of an inch to the rear side and 1½ inches of slope towards the center of the stable where a trap can be opened connected with a sewer to be used only in flushing out the stable with water. The floor of the cow stalls is raised four inches above the other parts of the stable floor including the walk behind the cows (Fig. 62), making the manure gutter eight inches deep on the side to the cow and only four inches deep on side to the passage behind. This gives all the advantages of a gutter eight inches deep and at the same time facilitates the removal of the manure, and lessens the liability to danger from cows stepping suddenly into a deep trench as they pass onto or back from the platform on which they stand.

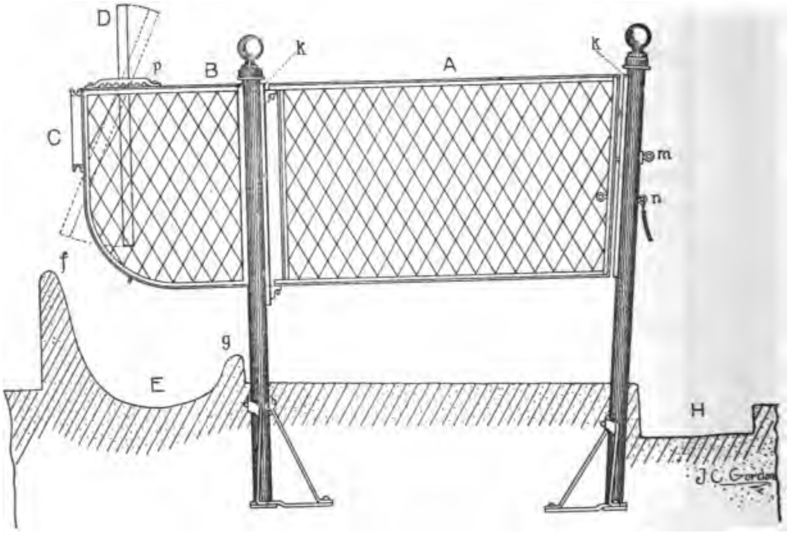

FIG. 62—Cross-section of cow-stall and stable floor, showing location of manger and manure gutter. A, gate; B, front side panel: C, frame work supporting side panel; D, swinging panel; E, manger; f, g, sides of manger; H, manure gutter; k, k, gate bars; m, pin arranged with a spring for fastening gate; n, eye for chain; p, arrangement for moving swinging panel.

Mangers.— The mangers are built up from and composed of the same material as the floor. A cross-section of the floor and mangers of the cow stable is shown in Fig. 62. The side of the manger next to the cow (g) is eight inches high and three inches thick, rounding down into the bottom as shown at (E). The front side of the manger (f) is sixteen inches high and built in a similar manner. This manger is two feet six inches wide and reaches from one end of the stable to the other. It is used both as a feeding manger and as a watering device. It may not be out of place to here state that this means of watering cows is just as convenient and satisfactory as any of the individual watering devices, while it is more cleanly and wholesome. The water flows into the manger at either end from a pipe, and as the mangers slope toward the center from both ends it is very readily drained into the sewer by opening a valve after the cows have had sufficient time to drink.

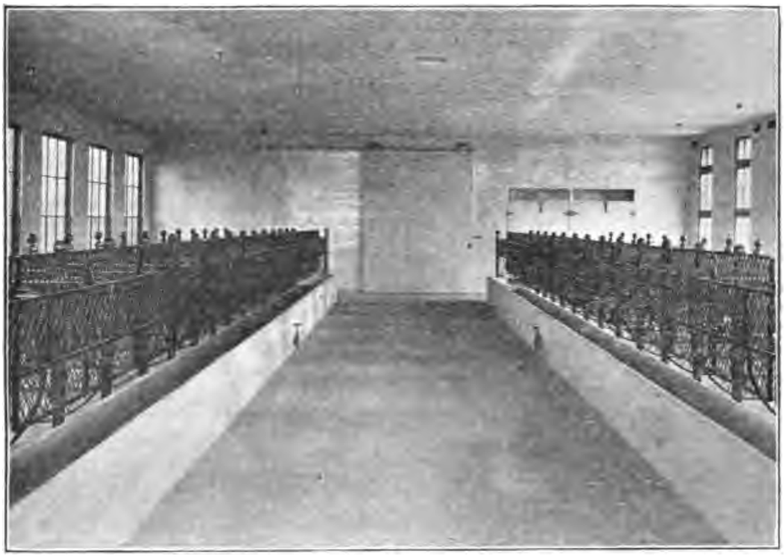

FIG. 63.—Passage between cow stalls, showing front of stalls and mangers.

Stalls.—The stable is arranged for thirty-six cows in stalls, eighteen on either side of the center passage, with the two rows of cows facing each other (Fig. 63). The center passage is 10 feet wide so that a team may be driven through to feed green crops taken directly from the fields. The stalls are constructed of gas pipe posts with frame-work of gates and panels of channel-iron supporting a mesh of No. 7 woven steel wire. (Figs. 63, 64, 65 and 66.)

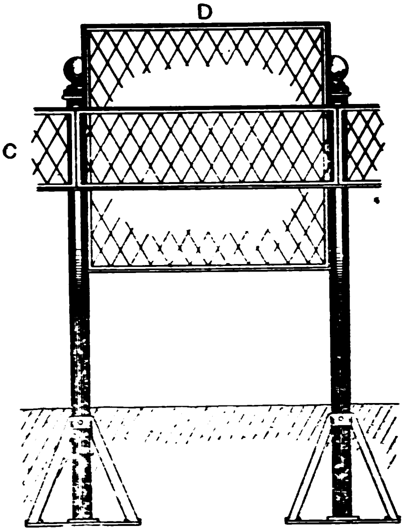

FIG. 64.—Front view of cow stall.

The figures show how the posts are anchored in a cement foundation. The letter C indicates the frame-work extending the length of each row of stalls to support the front part of the side panels and give them rigidity. D indicates the swinging panel which may be moved (see P)

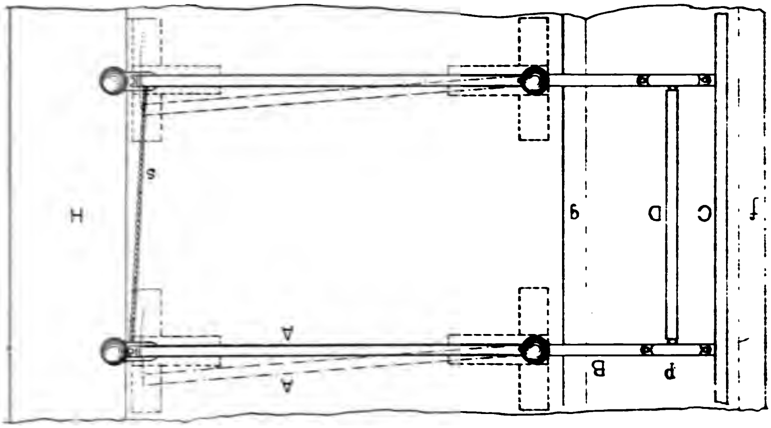

FIG. 65.—Plan of cow stall.

to suit the length of the cow, forcing a small cow to stand well back in her stall that the droppings are received into the manure gutter and not on the floor of the stall. The side panels of the stalls are hinged to accommodate the milkers and allow the cows to pass out without backing over the manure gutter.

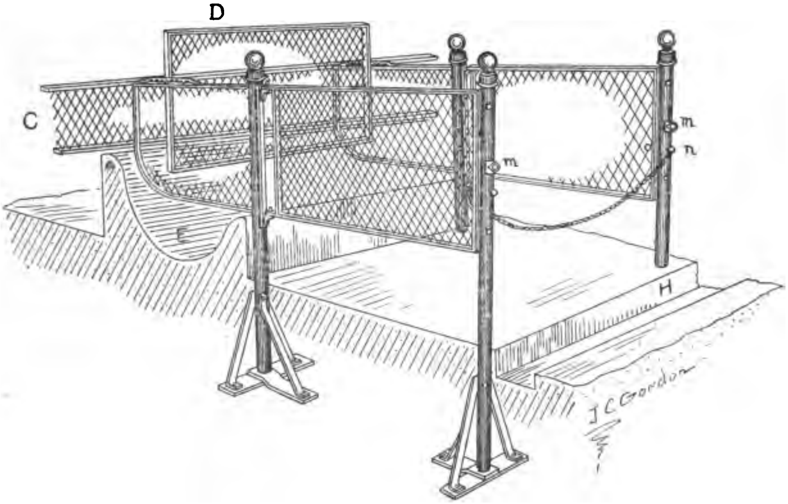

FIG. 66.—Perspective view of improved cow stall.

Young stock stable.—The right wing of the barn, 70 feet long by 30 feet wide, is designed for young stock and bulls. Like the cow stable it is lined with the galvanized iron and finished throughout with iron fittings. The partitions of the stalls are gas pipe imbedded in the cement floor at one end as shown in Fig. 67. This stable also has mangers of cement except for the very young calves. As seen in the illustration, every fourth bar in the partition separating the stalls from the passage way is a swinging bar or stanchion. The animals young and old in this table, until the approach of parturition in the heifers, are allowed the freedom of their stalls except at feeding time when they are fastened in the stanchions until feeding is finished.

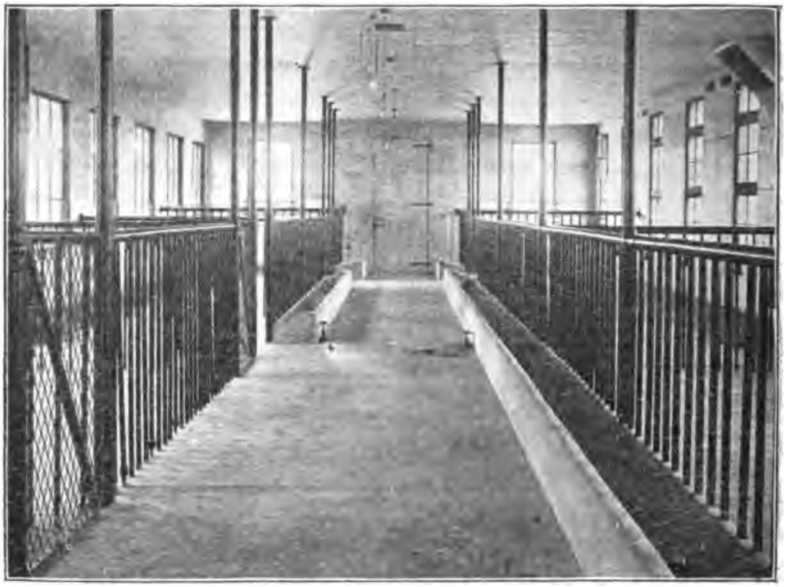

FIG. 67.—Young stock stable, showing arrangement of stanchions and mangers.

Bull stalls.—The bull stalls are similar to those for the young stock with the exception of there being but one heavy stanchion. The bars are heavier and stronger, and the gate to the stall is made of iron gas pipe, as shown in Fig. 68.

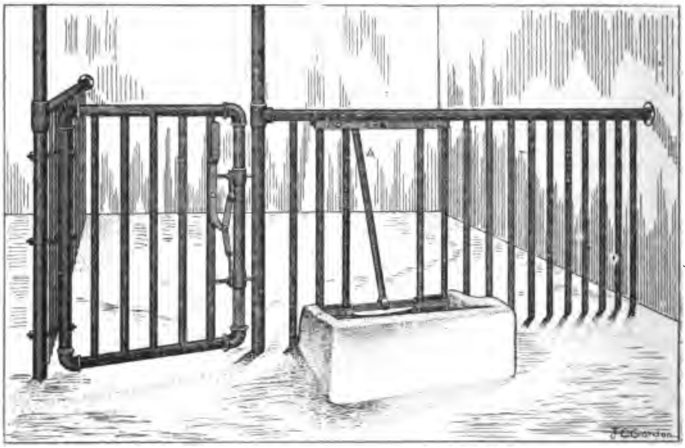

FIG. 68.—Perspective view of bull stall, showing gate and stanchion.

Basement.—Under the main part of the barn is a basement divided into two rooms. One of these is for the storage of roots and other products, while in the other is located the heating plant, the farm work shop, and the artesian well with a power pump operated by a 3 H. P. electric motor. This pump forces water into a large steel tank above the silo from which a supply is drawn through underground pipes to all the farm buildings.

Silo.—The silo is circular in form, eighteen feet inside diameter and thirty-three feet deep. It is a frame structure lined outside and inside with brick. On the inner brick surface is a heavy coating of Portland cement, making it practically water tight. As stated before, the silo is filled from the upper floor of the barn; when taking out the silage for feeding it falls through a box chute to the main floor where it is received into a truck (Fig. 69) by which it is conveyed to the mangers of the animals.

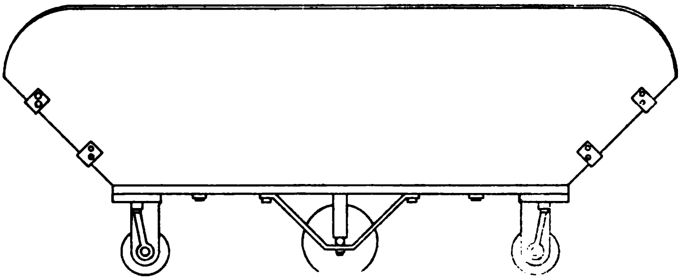

FIG. 69.—Ensilage truck.

Ventilation.—The system of ventilation originated by Prof. King for use in the stables is shown in Fig. 70, and is thus described by him:

A single ventilating flue D E rises above the roof of the main barn, and is divided below the roof into two arms A B D, which terminate at near the level of the stable floor at A A. These openings are provided with ordinary registers, with valves, to be opened and closed when desired. Two other ventilators are placed at B B, to be used when the stable is too warm, but are provided with valves to be closed at other times. C is a direct 12-inch ventilator leading into the main shaft, and opening from the ceiling,

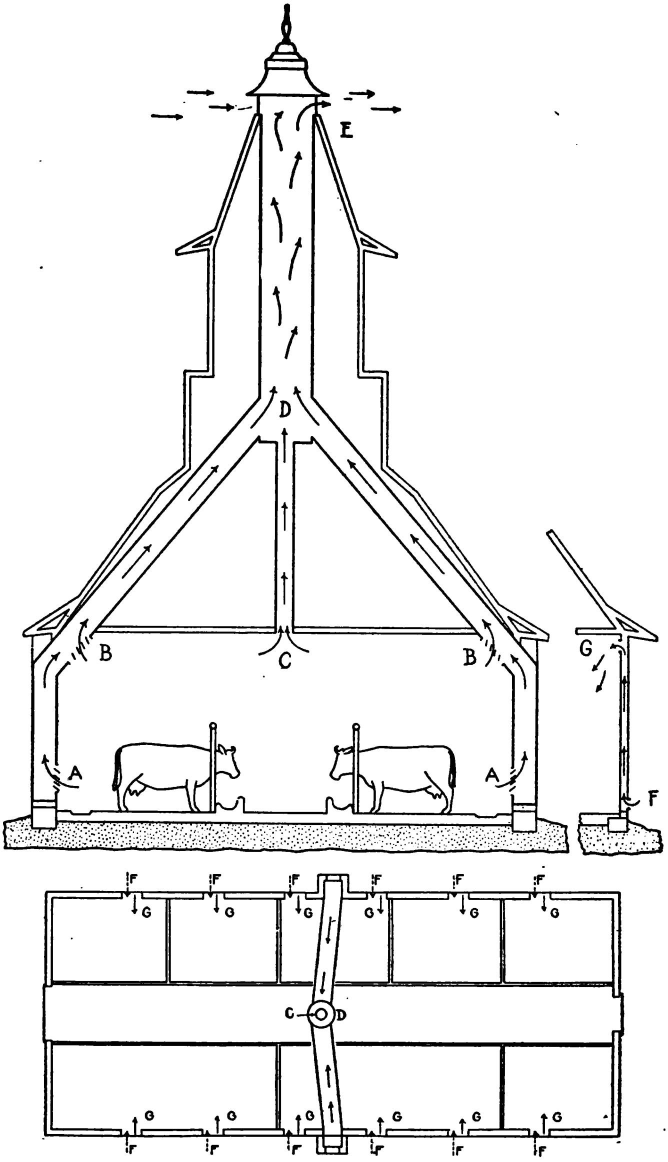

FIG. 70.—Cross-section of barn, showing system of ventilation.

so as to admit a current of warm air at all times to the main shaft to help force the draft. This ventilating shaft is made of galvanized iron, the upper portion being 3 ft. in diameter. The covering on the outside is simply for architectural effect. The air enters the stable at various points as shown in the plan at F G, and in the vertical section by arrows at F G.

THE WISCONSIN FERTILIZER LAW.

AN ACT to regulate the sale of commercial fertilizers.

[Laws of Wisconsin 1895, Chapter 87.]

The people of the State of Wisconsin, represented in senate and assembly, do enact as follows:

SECTION 1. Every manufacturer, company or person who shall sell, offer or expose for sale in this state any commercial fertilizer, or any material used for fertilizing purposes, the price of which exceeds ten dollars per ton, shall affix to every package of such fertilizer, in a conspicuous place on the outside thereof, a plainly printed statement clearly and truly certifying the number of net pounds in the package sold, or offered for sale, name or trade mark under which the article is sold, the name of the manufacturer or shipper, the place of manufacture, the place of business and a statement of the following fertilizing constituents, namely: the percentage of nitrogen in an available form, the percentage of potash soluble in water, and the percentage of available phosphoric acid, soluble and reverted, as well as total phosphoric acid.

SECTION 2. Every manufacturer, company or person who shall offer or expose for sale in this state any commercial fertilizer or material used for fertilizing purposes, the price of which exceeds ten dollars per ton, shall for each and every fertilizer bearing a distinguishing name or trade mark, file annually with the director of the agricultural experiment station of the University of Wisconsin, between the first and last days of December, a certified copy of the statement named in section 1 of this act, said certified copy to be accompanied, when required, by a sealed glass jar or bottle containing at least one pound of the fertilizer to be sold or offered for sale, and the company or person filing said certified copy with its accompanying sample of fertilizer, shall thereupon make affidavit that the said sample corresponds within reasonable limits to the fertilizer which it represents, in the percentage of nitrogen in an available form, total and available phosphoric acid, and potash soluble in water, which it contains, said affidavit to apply to the entire calendar year next succeeding the date upon which it is made. Additional brands may be offered for sale during the year, provided samples and affidavits are filed as above directed at least one month before such brands of fertilizers are offered for sale, in which case an analysis fee of double the usual amount must be paid. The deposit of the sample of fertilizer as herein provided, shall be required by said director, unless the company, manufacturer or persons selling or offering for sale a fertilizer coming within the provisions of this act, shall certify that its composition for the succeeding year is to be the same as given in the last previously certified statement, in which case the requiring of the said sample shall be at the discretion of said director.

SECTION 3. The director of the agricultural experiment station shall analyze or cause to be analyzed all the samples of fertilizers which come into his possession under the provision of section 2 of this act, and shall publish the results thereof in a bulletin or report on or before the first day of April next succeeding.

SECTION 4. Any manufacturer, importer, agent or seller of any commercial fertilizer coming within the provisions of this act, shall pay annually to the director of the Wisconsin agricultural experiment station, for each brand of fertilizers sold within the state a fee of twenty-five dollars, and upon fulfilling the requirements laid upon him by this act, shall for each brand receive from the director a certificate of compliance with this act, which certificate shall be a license permitting a sale of the same within the state for the calendar year for which the fee is paid. All fees received by said director shall be paid by him into the treasury of said experiment station.

SECTION 5. Any manufacturer, importer or person who shall sell, offer or expose for sale in this state any commercial fertilizer without complying with the requirements of sections one, two and four of this act, or any fertilizer which contains substantially a smaller percentage of constituents than are certified to be contained, shall, on conviction in a court of competent jurisdiction, be fined one hundred dollars for the first offense, and two hundred dollars for each subsequent offense.

SECTION 6. The director of the Wisconsin experiment station shall annually analyze, or cause to be analyzed, at least one sample of every fertilizer sold or offered for sale under the provisions of this act. Said director is hereby authorized in person or by deputy to take a sample, not exceeding two pounds in weight, for said analyses, from any lot or package of fertilizer or any material used for manurial purposes which may be in the possession of any manufacturer, importer, agent or dealer in this state; but said sample shall be drawn in the presence of said party or parties in interest, or their representatives, and taken from a parcel or a number of packages which shall not be less than ten per cent. of the whole lot sampled, and shall be thoroughly mixed and then divided into equal samples and placed in glass vessels and carefully sealed and a label placed on each, stating the name or brand of the fertilizer or material sampled, the name of the party from whose stock the sample was drawn and the time and place of drawing, and said label shall also be signed by the director or his deputy and by the party or parties in interest or their representative at the drawing and sealing of said samples; one of said duplicate samples shall be retained by the director and the other by the party whose stock was sampled; and the sample or samples retained by the director shall be for comparison with the certified statement named in section two of this act. The result of analysis of the sample or samples so procured shall be reported to the person or persons requesting the analysis and shall also be published in a report or bulletin within a reasonable time.

SECTION 7. It shall be the duty of the director of the Wisconsin agricultural experiment station to enforce the provisions of this act, and to prosecute or cause to be prosecuted any party or parties violating the same.

SECTION 8. This act shall take effect from and after December 1st, 1895.

Approved March 23, 1895.

EXCHANGES.

The Station takes pride in the fact that it has on file an almost complete list of the leading agricultural papers in the United States, besides many from foreign countries, and some not strictly treating of agriculture. These papers come to the Station in exchange for its reports and bulletins. While of the highest value to those connected with the Station as the expression of agricultural experience and sentiment, they are placed where they can be read and referred to by the agricultural students and others of the University, as well as by visitors. Any one desiring sample copies of these papers can as a rule secure them upon application to the publishers, at the addresses given.

FOREIGN EXCHANGES.

Agricultural Gazette, London, England.
Agricultural Journal, Cape Town, South Africa.
Agricultural Times, Llwyn, Llanfyllin, England.
Analyst, London, England.
Australian Ironmonger, Melbourne, S. Australia.
Australian Farm and Home, Melbourne, Victoria, Australia.
Bulletin des Seances de la Societe Nationale d'Agriculture de France, Paris, France.
Chronique Agricole du Canton du Vaud, Lausanne, Switzerland.
Co-operative Farmer and Maritime Dairyman, Sussex, N. B.
Country Sport and Messenger of Agriculture, London, England.
Dairy, London, England.
Extrait des Travaux de la Soc. Centr. d'Agr. de la Seine Inf., Rouen, France.
Farmer's Advocate, London, Ontario.
Farming, Toronto, Canada.
Field, London, England.
Journal für Landwirtschaft, Berlin, Germany.
Journal of the Bath and West of England Society, London, Eng.
Journal of the British Dairy Farmers' Ass'n, London, Eng.

Journal of the Council of Agriculture, Hobart, Tasmania.

Journal of Royal Agricultural Society of England, London, Eng.

Kgl. Landtbruks-Akademiens Handlingar och Tidskrift, Stockholm, Sweden.

L'Agricultura Moderna, Milan, Italy.

Landbouwgalm, Kortrijk, Belgium.

Landmandsvennen, Bergen, Norway.

Landwirtschaftliche Wochenblatt f. Schlesw.-Holstein, Kiel, Germany.

Le Messager Agricole, Montpellier, France.

L'Industrie Laitiere, Paris, France.

Live Stock Journal, London, England.

Milch Zeitung, Bremen, Germany.

Mittheilungen des Milchw. Vereins im Allgäu, Memmingen, Germany.

Neue Zeitschrift für Rübenzucker Industrie, Berlin, Germany.

North British Agriculturist, Edinburgh, Scotland.

North West Farmer, Winnipeg, Manitoba, Canada.

Rural Canadian, Toronto, Canada.

Tidsskrift for det norske Landbrug, Christiania, Norway.

Tidsskrift for Landoekonomi, Copenhagen, Denmark.

Ugeskrift for Landmaend, Copenhagen, Denmark.

Weekly Times, Melbourne, Australia.

West Indian Home Builder, Barbados, W. I.

Zeitschrift für Nahrungsmittel-Untersuchung und Hygiene, Vienna, Austria.

Zeitschrift des Landw. Vereins in Bayern, Munich, Germany.

DOMESTIC EXCHANGES.

Acker-und Gartenbau Zeitung, Milwaukee, Wis.

Agricultural Epitomist, Indianapolis, Ind.

American Agriculturist, New York City.

American Cheesemaker, Grand Rapids, Mich.

American Corn and Hog Journal, Sibley, Ill.

American Cultivator, Boston, Mass.

American Grange Bulletin, Cincinnati, O.

American Sheep Breeder and Wool Grower, Chicago, Ill.

American Swineherd, Chicago, Ill.

American Thresherman, Madison, Wis.

Baltimore Weekly Sun, Baltimore, Md.

Blooded Stock on the Farm, Stock, Pa.

Boston Weekly Globe, Boston, Mass.

Breeder's Gazette, Chicago, Ill.

Bulletin of the American Devon Cattle Club, Wheeling, W. Va.

California Cultivator, Los Angeles, Cal.

Chicago Produce, Chicago, Ill.

Colman's Rural World, St. Louis, Mo.
Connecticut Farmer, Hartford, Conn.
Country Gentleman, Albany, N. Y.
Cotton Planters' Journal, Memphis, Tenn.
Creamery Gazette, Des Moines, Iowa.
Creamery Journal, Waterloo, Iowa.
Cultivator, Omaha, Neb.
Dairy World, Chicago, Ill.
Detroit Free Press, Detroit, Mich.
Deutsche-Amerikanische Müller, Chicago, Ill.
Dixie Miller, Nashville, Tenn.
Dorset Courier, Washington, Pa.
Drainage and Farm Journal, Indianapolis, Ind.
Elgin Dairy Report, Elgin, Ill.
Fanciers' Review, Chatham, N. Y.
Farm and Fireside, Springfield, Ohio.
Farm and Home, Springfield, Mass.
Farm Magazine, Knoxville, Tenn.
Farm News, Springfield, Ohio.
Farm Students' Review, St. Anthony Park, Minn.
Farm und Haus, Madison, Wis.
Farmer, The, St. Paul, Minn.
Farmer and Breeder, Springfield, Ill.
Farmers' Guide, Huntington, Ind.
Farmers' Home, Dayton, Ohio.
Farmers' Home Journal, Louisville, Ky.
Farmers' Magazine, Springfield, Ill.
Farmers' Review, Chicago, Ill.
Farmers' Union, Chicago, Ill.
Farmers' Voice, Chicago, Ill.
Farm, Field and Fireside, Chicago, Ill.
Farm Journal, Philadelphia, Pa.
Farm, Stock and Home, Minneapolis, Minn.
Field and Farm, Denver, Colo.
Florist's Exchange, New York City.
Forester, Princeton, N. J.
Freeman's Farmer, North Yakima, Wash.
Geflügel Züchter, Wausau, Wis.
Gentleman Farmer Magazine, Chicago, Ill
Grange Visitor, Charlotte, Mich.
Green's Fruit Grower, Rochester, N. Y.
Hoard's Dairyman, Ft. Atkinson, Wis.
Holstein-Friesian Register, Brattleboro, Vt.
Home and Farm, Louisville, Ky.
Horticultural Gleaner, Austin, Tex.
Hospodar, Omaha, Neb.

Illinois Staats-Zeitung, Chicago, Ill.
Indiana Farmer, Indianapolis, Ind.
Industrial American, Lexington, Ky.
Industrialist, Manhattan, Kas.
Iowa Homestead, Des Moines, Ia.
Irrigation Age, Chicago, Ill.
Jersey Bulletin, Indianapolis, Ind.
Kansas Farmer, Topeka, Kas.
Live Stock Indicator, Kansas City, Mo.
Live Stock Report, Chicago, Ill.
Louisiana Planter, New Orleans, La.
Market Basket, Philadelphia, Pa.
Market Gardener, Minneapolis, Minn.
Mayland Farmer, Baltimore, Md.
Michigan Farmer, Grand Rapids, Mich.
Midland Poultry Journal, Kansas City, Mo.
Mirror and Farmer, Manchester, N. H.
Moulton's Monthly, New York City.
National Stockman, Pittsburg, Pa.
Nebraska Farmer, Lincoln, Neb.
New England Farmer, Boston, Mass.
New England Florist, Boston, Mass.
New England Homestead, Springfield, Mass.
New York Produce Review and American Creamery, New York City.
Northwestern Agriculturist, Minneapolis, Minn.
Northwestern Horticulturist, Tacoma and Seattle, Wash.
Northwest Weather and Crops, Minneapolis, Minn.
Ohio Farmer, Cleveland, Ohio.
Orange Judd Farmer, Chicago, Ill.
Oregon Agriculturist, Portland, Ore.
Pacific Rural Press, San Francisco, Cal.
Pharmaceutical Review, Milwaukee, Wis.
Poultry Monthly, Albany, N. Y.
Practical Dairyman, Indianapolis, Ind.
Practical Dairyman and Agriculturist, Chatham, N. Y.
Practical Farmer, Philadelphia, Pa.
Prairie Farmer, Chicago, Ill.
Public Ledger, Philadelphia, Pa.
Rural Californian, Los Angeles, Cal.
Rural Life, Waterloo, Iowa.
Rural New Yorker, New York City.
Weekly Call, San Francisco, Cal.
Southern Agriculturist, Nashville, Tenn.
Southern Cultivator, Atlanta, Ga.
Southern Farmer, New Orleans, La.

Southern Farm Magazine, Baltimore, Md.
Southern Live Stock Journal, Starkville, Miss.
Southern Planter, Richmond, Va.
Southern States, Baltimore, Md.
Southwest, The, Springfield, Mo.
Strawberry Culturist, Salisbury, Md.
Strawberry Specialist, Kitrell, N. C.
Successful Farmer, Sioux Falls, S. D.
Sugar Beet, Philadelphia, Pa.
Texas Farm and Ranch. Dallas, Texas.
Tobacco Leaf, New York City.
Wallace's Farmer, Des Moines, Iowa.
Western Agriculturist and Live Stock Journal, Chicago, Ill.
Western Creamery, San Francisco, Cal.
Western Rural, Chicago, Ill.
Western Soil Culture, Sioux City, Iowa.
Western Stockman and Cultivator, Omaha, Neb.
Western Swineherd, Genesee, Ill.
Wisconsin Agriculturist, Racine, Wis.
Wisconsin Farmer, Madison, Wis.
Wool Record, New York City.
Wool and Sheep Markets, Chicago, Ill.
Weather and Crops, Chicago, Ill.

STATE PAPERS.

The Record, Algoma, Wis.
Langlade County Special, Antigo, Wis.
The Eagle, Augusta, Wis.
The Times, Augusta, Wis.
The Courant, Berlin, Wis.
Jackson County Journal, Black River Falls, Wis.
Independent, Brodhead, Wis.
Register, Brodhead, Wis.
Rock County Banner, Clinton, Wis.
Advocate, Cumberland, Wis.
Enterprise, Deerfield, Wis.
Chronicle, Dodgeville, Wis.
Sun, Dodgeville, Wis.
The Leader, Eau Claire, Wis.
The Telegram, Eau Claire, Wis.
The Times Review, Fennimore, W
The Journal, Grantsburg, Wis.
The News, Hammond, Wis.
Weekly Press, Highland, Wis.
The Sentry, Hillsboro, Wis.
The Independent, Juneau, Wis.
The Republican & Leader, La Crosse, Wis.
Reporter, Lancaster, Wis.
Weekly Teller, Lancaster, Wis.
The Herald, Lake Geneva, Wis.
Lincoln County Anzeiger, Merrill, Wis.
Lodi Valley News, Lodi, Wis.
Tribune, Manitowoc, Wis.
The Wisconsin Leader, Merrillan, Wis.
Winnebago Anzeiger, Menasha, Wis.
The Republican, Necedah, Wis.

Press, New London, Wis.
St. Croix Republican, New Richmond, Wis.
The Voice, New Richmond, Wis.
Republican, Oconomowoc, Wis.
La Crosse County Record, Onalaska, Wis.
Observer, Oregon, Wis.
Enterprise, Palmyra, Wis.
Press, Poynette, Wis.
Free Press, Reedsburg, Wis.
The Times, Reedsburg, Wis.
The Chronotype, Rice Lake, Wis.
The Telegram, Sheboygan, Wis.
Sheboygan County News, Sheboygan Falls, Wis.
Watchman, Shell Lake, Wis.
News, Shiocton, Wis.
Republican, Stanley, Wis.
The Post, Stevens Point, Wis.
Door County Advocate, Sturgeon Bay, Wis.
Door County Democrat, Sturgeon Bay, Wis.
Journal, Tomah, Wis.
Herald, Trempealeau, Wis.
The Post, Waupaca, Wis.
Waupun Leader, Waupun, Wis.
Wonewoc Reporter, Wonewoc, Wis.

ACKNOWLEDGMENTS.

From P. M. Sharples, West Chester, Pa. Framed lithograph.

From Constantine Wagner, New York. One Wagner's double-bore skim milk test bottle, one Wagner's "up to date" milk measuring pipette.

From A. H. Reid, Philadelphia, Pennsylvania. One Reid's pasteurizer, one Reid cream cooler.

From Creamery Package Mfg. Co., Chicago, Ill. One 75 gal. Pott's pasteurizer.

From C. H. Van Alstyne, Marqueta, Ia. One automatic milk scale.

From D. H. Burrell, Little Falls, N. Y. One 24 bottle "Facile" turbine Babcock milk tester.

From Gem Fibre Package Co., Detroit, Mich. 200 Fibre Packages for shipping butter.

From A. J. Decker, Fond du Lac, Wis. One gallon Eilerson's Rennet extract, one 12 bottle Wisconsin Curd Test.

From Roehgsterger & Gerber, New York. ¼ pound Dr. Witte's rennet powder.

From Standard Oil Co., New York. 25 lbs. paraffine cheese coating.

From A. J. Lumsden, Plymouth, Wis. 200 cheese bandages.

From Delegation d. vereinigten Saltpeter-Producenten, Berlin-Charlottenburg, Germany, by Mr. G. Schmidt: pamphlets and charts showing effects of nitrate fertilization; Ergebnisse von Düngungs-versuchen v. Prof. Dr. Paul Wagner, Darmstadt; Düngungs-versuche mit Chilisalpeter v. Prof. Dr. Paul Wagner, Darmstadt.

From U. S. Department of Agriculture, Washington, D. C. 220 lbs. Kleinwanzleben Elite sugar beet seed; 412 lbs. Vilmorin Improved sugar beet seed; 50 lbs. Zeringen seed grown by Strandes, Germany.

From Prof. Dr. M. Hollrung, Halle a. S., Germany. One copy of Hollrung, Chemische Mittel gegen Pflanzenkrankheiten.

From Prof. W. A. Henry, Madison, Wis. One copy of Henry, Feeds and Feeding.

From German Kali Works, New York, N. Y. One bag silicate of potash (220 lbs.). One bag high-grade sulfate of potash. Copies of Mittheilungen über Düngungsversuche, 1897.

From Armour Fertilizer Works, Chicago, Ill. 300 lbs. bone superphosphate.

From Dr. Benno Martiny, Berlin, Germany. Samples of dairy salt.

From Dr. Ed. Freudenreich, Berne, Switzerland. Sample of dairy salt.

From Director F. H. Werenskiold, Christiania, Norway. Samples of dairy salt.

Prom Prof. J. P. Sheldon, Sheen, Ashbourne, England. Sample of dairy salt.

From Prof. James Long, Burleigh, Cheshunt, England. Sample of dairy salt.

From Dairy Councilor B. Böggild, Copenhagen, Denmark. Sample of dairy salt.

From Inspecteur Adj. Paul de Vuyst, Gand, Belgium. Samples of dairy salt.

From Dr. P. Vieth, Hameln, Germany. Samples of dairy salt.

From Mr. Johs. Siedel, Güstrow, Germany. Samples of dairy salt.

From Dr. C. Besana, Lodi, Italy. Samples of dairy salt.

From Dr. Felix Gabriel, Friedland, Bohemia. Samples of dairy salt.

From Prof. H. H. Dean, Guelph, Canada. Samples of dairy salt.

From Prof. R. Leze, Buc, pres Versailles, France. Samples of dairy salt.

From Prof. H. M. Cottrell, Manhattan, Kan. Sample of dairy salt.

From Baums Castorine Co., Syracuse, N. Y., 100 lbs. of Baum's Horse and Stock Food.

From Zenoleum Disinfectant Co., Detroit, Mich., 5 gals. "Zenolium" Sheep Dip.

From Scab Cure Dip Co., Chicago, Ill., sample package of Sheep Dip.

From W. Atlee Burpee & Co., Philadelphia, Pa. Twenty packages of vegetable seeds; twenty-six packages of flower seeds.

From F. L. Creuger, Monroe, Wis. One package of apple cions.

From G. W. Cairnes, Ellsworth, Wis. Two packages of apple cions.

From O. M. Lord, Minnesota City, Minn. Twelve glass jars of preserved native wild plums; also a collection of plum pits.

From Wm. Toole, Baraboo, Wis. Twelve packets of flower seeds, one tree Baraboo plum.

From B. A. Matthews, Knoxville, Ia. One package of plum cions.

From E. H. S. Dartt, Owatonna, Minn. One package of plum cions.

From Franklin Johnson, Baraboo, Wis. One package of plum cions.

From H. Knudson, Springfield, Minn. One packages of plum cions.

From Jas. Wood, Windom, Minn. Two package of plum cions.

From Edson Gaylord, Nora Springs, Ia. One package of plum cions.

From Luther Burbank, Burbank Experiment Farms, Cal. One package of plum cions.

From Chas. Luedloff, Cologne, Minn. Three plum trees; one package of plum cions: one cherry tree.

From Wm. Henry Maule, Philadelphia, Pa. Two tubers of a new potato.

From Thos. Tanner, Omro, Wis. Twelve plants Bangor blackberry.

From L. L. Olds, Clinton, Wis. Two tubers of Pride of Michigan potato.

From M. E. Hinkley, Marcus, Ia. Two plum trees.

From C. S. Prath, Reading, Mass. Twelve plants Sample strawberry.

From Department of Agriculture, Washington, D. C. Twenty-four plants from Russia.

From Dr. A. B. Dennis, Cedar Rapids, Ia. One plum tree.

From J. H. Hale's Nurseries, So. Glastonbury, Conn. Six plants Maximum strawberry.

From Clarence Wedge, Albert Lea, Minn. One package trees of Parker plum.

From Henry Wallis, Wellston, Mo. One vine of Hicks grape.

From F. A. Waugh, Burlington, Vt. One package plum blossoms from Denton, Md.

From J. S. Harris, La Crescent, Minn. Five young trees of Oxford plum.

From J. Wragg & Sons, Waukee, Ia. One package cions of Klondike plums.

From Coe & Converse, Ft. Atkinson, Wis. Two trees of Norway maple.

From Thomas Frankland, Stonewall, Manitoba. One package of plum blossoms.

From L. H. Read, Grand Rapids, Wis. One package of seed potatoes.

From Adler Color & Chemical Works, New York, N. Y. One package green arsenite (Insecticide).

From Jewell Nursery Co., Lake City, Minn. Two trees of Holt apple.

From Withington & Cooley Mfg. Co., Jackson, Michigan, a collection of 16 garden and farm tools.

From J. M. Winfree, Addieville, Ill. One " bug exterminator."

From Arch. McNeilage, Secy., Glasgow, Scotland. Clydesdale Stud-Book, Vol. 20.

From R. Henry Rew, London, W. C., England. Oxford Down Flock Book, Vol. X, 1898.

From T. J. Other, Hargrave, Ripon, England. Wensleydale Flock Book, Vol. IX, 1898.

From C. R. Thomas, Independence, Mo. Am. Hereford Record, Vol. 18.

From John Risdon, Jr., Secy., Golsoncott, Washford, England. Davy's Devon Herd Book, Vol. 21, 1898.

From Mortimer Levering, Secy., American Shropshire Registry Association, LaFayette, Ind. American Shropshire Record, Vol. 12.

From Rev. John Gillespie, LL. D., Manswald Manse, Ruthwell, R. S. O., Dunfriesshire, England. Galloway Herd Book, Vol. XVIII.

From Ernest Prentice, 64 Oxford St., Ipswich, England. Suffolk Sheep Society Flock Book, Vol. 12.

FINANCIAL STATEMENT.

The Wisconsin Agricultural Experiment Station, in account with the United States appropriation.

1898.	Abstract.	Dr.	Cr.
To receipts from treasurer of the United States as per appropriation for the year ending June 30th, 1898, under act of congress, approved March 2d, 1887	....	$15,000 00	....
By salaries	1	....	$10,280 00
By labor	2	....	2,840 82
By publications	3	....	....
By postage and stationery	4	....	9 00
By freight and express	5	....	....
By heat, light and water	6	....	8 54
By chemical supplies	7	....	504 99
By seeds, plants and sundry supplies	8	....	118 90
By fertilizers	9	....	15 00
By feeding stuffs	10	....	345 02
By library	11	....	395 44
By tools, implements and machinery	12	....	89 72
By furniture and fixtures	13	....	....
By scientific apparatus	14	....	129 92
By live stock	15	....	209 00
By traveling expenses	16	....	38 65
By contingent expenses	17	....	15 00
By building and repairs	18	....	....
		$15,000 00	$15,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Wisconsin Agricultural Experiment Station for the fiscal year ending June 30, 1898; that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $15,000, and the corresponding disbursements $15,000, for all of which proper vouchers are on file and have been by us examined and found correct.

And we further certify that the expenditures have been solely for the purposes set forth in the act of congress approved March 2, 1887.

B. J. STEVENS,
GEO. H. NOYES,
WILLIAM F. VILAS,
(Signed) CHARLES KENDALL ADAMS,
Finance Committee.

ATTEST:

E. F. RILEY,
Custodian.

APPENDIX.

TABLE I.—*Record of wind velocities and water pumped by windmill on Physical Laboratory during the last 25 days of March, 1897, and first 6 days of March, 1898.*

Date.	Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	M.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
28— 1......	6	7	7	10	9	10	10	10	11	12	11	10	10	12	10	10	11	13	13	12	11	11	9	10
	0	0	0	0	1	1	1.4	1	1	2	2.1	1	1	2	1	1	3	1	4	2	3	2	1	1.4
1— 2......	14	19	20	23	21	17	20	21	20	15	18	19	19	21	18	20	17	15	17	15	17	18	16	16
	5	8	11	11	10	9	10	10	11	7	10	10	10	10	10	10	9	7	8	4	8	10	8	8
2— 3......	13	12	11	10	8	6	4	6	5	1	2	0	0	0	0	0	2	1	4	7	11	14	17	15
	2	2	2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	8	5
3— 4......	16	19	16	17	14	14	13	14	13	9	10	9	8	8	5	6	6	5	6	6	6	7	7	8
	8	7	7	5	4	3	3	4	1	0	4	5	5	5	0	2	0	0	0	0	0	0	0	0
4— 5......	7	5	3	2	0	4	6	10	10	7	7	4	3	5	8	9	5	7	6	4	7	14	15	10
	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	2	3	6	2
5— 6......	8	14	11	10	12	11	10	8	7	7	8	6	6	9	4	12	5	7	9	11	6	6	6	7
	2	3	3	2	2	3	1	0	0	0	0	0	0	1	0	2	0	1	1	2	1	0	0	0
6— 7......	17.0	14.5	14.5	14.0	14	14	12	11.5	10.5	9.0	7.5	9.5	14	10.5	11.0	10.5	14.0	14.0	13.0	11.0	10.0	10.5	13.5	13.0
	5.2	1	4	2	2	2	1	0	0	0	0	1	0	0	1	0	1	1	2	0	1	0	0	2
7— 8......	12.0	13.0	16.0	19.0	16.0	15.0	17.0	19.0	18.0	10.0	7.0	6.5	7.0	9.5	8.5	6.5	14.0	15.0	6.0	7.5	10.0	11.0	7.0	6.0
	0	2	3	7	5	3	4	4	2	0	0	0	0	0	0	1	2	1	0	1	0	0	0	0
8— 9......	5	5.5	9.0	7.0	5.5	6.0	8.0	6.0	5.0	4.5	5.5	4.5	8.0	7.0	8.0	8.0	9.0	9.0	14.0	16.0	20.0	21.0	16.0	16
	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	3	7	8	8.6	4.5	4.5
9—10......	19.0	23.0	20.0	15.0	17.0	15.0	16 0	16.0	17.0	20.0	20.0	17.0	13.0	16.0	15.0	12.0	9.0	5.0	8.0	8.0	9.0	8.0	11.0	10.0
	10	10	7	3	3	2	3	4	4	4	5	3	1	2	1	0	0	0	0	0	0	0	0	0
10–11......	13.0	15.0	15.0	13.0	14.0	10.0	8.0	6.0	4.0	5.0	6.0	5.0	5.0	7.0	11 0	10.0	9.0	9.0	6.5	10.5	11.0	10.0	10.0	11.0
	2	2	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11—12......	12.0	15.0	17.0	19.0	13.0	14.0	15.0	13.0	9.0	8.0	3.0	7.0	17.0	29.0	28.0	27.0	20.0	20.0	20.0	27.0	27.0	25.0	27.0	25.0
	1	3	5.2	6 3	2	4	4	2	1	0	0	1	5	8	7	7	6	8	10	10	11	10	9	9
12—13......	25.0	24.0	24.0	20.0	19.0	13 0	13.0	11.0	7.5	9.5	10.0	9.0	9.0	8.0	9.0	9.0	5.5	7.5	7.0	5.0	5.0	9.0	11.0	12.0
	11	10	9	9	8	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
13—14......	15.0	16.0	16.0	18.5	20.5	20.0	20 0	19.0	11.0	10.0	11.0	13.0	18 0	20.5	21.0	18.0	19.0	21.0	19.0	22.0	22.0	21.0	23.0	23.0
	3	5	3	5	7	9	7	8	4	0	0	0	4	8	9-	8	8	6	4	8	8	6.6	8.8	8.8
14—15......	24.0	22.0	17.0	19.0	15.0	16.0	12.0	10.0	9.0	8.0	7.0	6.0	3.0	2.5	5.0	6.0	5.0	4.0	6.0	5.0	6.0	9.0	7.0	7
	9	8	5.2	6.3	3	4.5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]	0
15—16......	8.0	9.0	9.0	6.0	7.0	8.0	7.0	5.0	4.0	3.0	3.5	3.5	3.5	4.0	5.0	3.0	3.0	3.0	2.0	5.0	8.0	13 5	11.0	14.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0	2.9
16—17......	16.0	13.0	13.0	13.0	12 0	11.0	11.0	10.0	9.0	9.0	8.0	8.0	7.5	9.5	9.0	10.0	10.0	9.0	9.0	11.0	12.0	10.0	8.0	9.0
	4.5	1.4	1.4	1.4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
17—18......	14.0	13.0	14.0	13.0	13.0	13.0	13.0	10 0	10.0	12.0	21.0	16.0	12.0	16.0	16.0	13.0	15.0	11.0	10.0	8.0	7.0	8.0	4.0	2.0
	2.9	1.4	2 9	1.4	1.4	1.4	1.4	0	0	1	8.6	4.5	1	4.5	4.5	1.4	3	0	0	0	0	0	0	0
18—19......	4.0	4 0	3.5	5.5	4.0	5.0	4.0	4.0	6.0	7.0	6.0	7.0	7.0	9.0	11.0	12.0	11.0	11.0	11.0	10.0	10.5	10.5	12.0	6
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
19—20......	9.0	7.0	7.0	5.5	5.5	5.0	3.5	4.0	5.0	8.0	11.0	12.0	16.0	12.0	13.0	16 0	18.0	17.0	16.0	14.0	13.0	11.0	15.0	13.0
	0	0	0	0	0	0	0	0	0	0	0	1	4.5	1	1.4	4.5	6,1	5.2	3	6	4	3	3	3
20—21......	18.0	20.0	22.0	19.0	19.0	17.0	21.0	20.0	19.0	16.0	13.0	9.0	10.0	13.0	9.0	8.0	13.0	9.0	5.0	4.0	4.0	4.0	4.0	6.0
	4	6	8	8	9	7	10	10	10	6	3	2	2	4	1	0	0	0	0	0	0	0	0	0
21—22......	6.0	5.0	12.0	15.0	18.0	15.0	12.0	12.0	15.0	18.0	15.0	13.0	15.0	16.5	16.0	15.0	16.0	17.0	17.0	19.0	16.0	16.0	17.0	16.0
	0	0	1	3	2	3	0	0	4	5	4	2	4	4	4	2	5	6	7	8	3	4.5	8	7
22—23......	14.0	17.0	14.0	15.0	14.0	12.0	8.0	5.0	4.0	4.5	5.5	7.0	11.0	12.0	16.0	25.0	21.0	19.0	18.0	22.5	24.0	27.0	27.0	23.0
	8	7	3	4	3	1	0	0	0	0	0	0	0	1	4	6	3	6.3	8	9	9	10	10	8.8
23—24......	25.0	27.0	28.0	29.0	31.0	31.0	33.0	27.0	28.0	33.0	30.0	27.0	26.0	24.0	22.0	23.0	25.0	23.0	25.0	23.0	22.0	23.0	24.0	16.0
	8.8	11	8	4	7	7	4	9.6	9.3	10	10	9.6	9.4	9	8	8.8	8.8	8.8	8.8	8.8	5	6	6	4
24—25......	19.0	18.0	16.0	19.0	18.0	17.0	17.0	15.0	13.0	14.0	15.0	15.0	13.0	14.0	13.0	11.0	12.0	10.0	10.0	9.0	11.0	14.0	17.0	11.0
	5	3	4	4	6.1	5.2	2	3	1	2	3	1	1	2	2	0	0	0	0	0	0	2	4	3
25—26......	16.0	15.0	15.0	16.0	14.5	13.5	11.0	13.0	12.0	10.5	12.0	12.0	11.0	13.0	11.0	11.0	12.0	12.0	11.0	12.0	13.0	17.0	25.0	24.0
	3	2	3	3	4	1	0	1.4	1	0	1	1	0	1.4	0	0	1	0	0	0	0	2	5	5
26—27......	21.0	25.0	22.0	23.0	18.0	17.0	15.0	16.0	16.0	17.0	17.0	14.0	14.0	11.0	11.5	10.5	7.0	5.0	6.0	10.0	8.0	4.0	4.0	4.0
	10	9	8	8.8	6.0	8	4	6	6	6	7	6	3	0	0	0	0	0	0	0	0	0	0	0
27—28......	5.0	3	3.0	2.0	2.0	2.0	5.0	6.0	7.0	10.0	7.0	5.0	6.0	8.0	5.0	7.0	6.0	6.0	8.5	11.0	16.0	15.0	19.0	14.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	3
28—29......	16.0	16.0	16.0	15.0	15.0	13.0	14.0	14.0	7.0	6.0	7.0	7.0	10.0	10.0	8.0	6.0	7.0	8.0	9.0	13.0	12.0	13.0	13.0	12.0
	7	6	6	4	4	3	3	3	1	0	0	0	0	0	0	0	0	0	0	1	2	1	0	0
29—30......	13.0	13.0	12.0	11.0	10.0	10.0	10.0	8.0	7.0	6.0	4.0	5.0	5.0	4.0	5.0	5.0	5.5	5.5	4.0	8.0	8.5	11.0	11.5	1 0
	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
30—31......	15.0	17.0	15.0	13.0	12.0	8.0	10.0	10.0	13.0	14.0	14.0	12.0	13.0	13.5	12.0	12.5	13.0	15.0	15.0	18.0	20.0	19.0	18.0	1 0
	2	5	3	1.4	1	0	0	0	3	2	5	2	0	1	1	0	1	2	6	6.1	6	5	8	
Totals...	425.0 113.4	446.0 112.8	438.0 111.8	436.5 101.6	411.0 94.5	382.5 80.1	378.5 61.8	365.5 67.0	332.0 60.3	323.0 46.0	322.0 62.7	298.0 50.1	319.0 50.9	354.5 64.9	344.0 54.9	352.0 55.7	347.0 56.9	433.0 53.3	331.0 64.8	363.5 75.1	383.5 74.0	410.0 85.1	427.0 95.3	388.0

EXPLANATION OF TABLE.

Table I. In this table the numbers in the lines opposite the date express the number of miles of wind recorded for the hour of the day given at the top of the column. The numbers in the lines against which n

TABLE I.—Continued.—*Record of wind velocities and water pumped by windmill on Physical Laboratory during April, 1897.*

Date.	Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	M.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
31- 1.......	25.0	25.0	25.5	25.5	28.0	27.0	24.0	23.5	22.5	23.0	23.0	22.0	19.0	19.0	19.0	18.0	19.0	19.0	19 0	22.0	24.0	23.0	24.0	22.0
	8	9	10	10	9	8	8	7	9	8	9	9	7	7	6	7	6	7	7	8	9	8	8	8
1- 2.......	29.0	29.0	25.0	24.0	25.0	21.0	17.0	14.0	12.0	14.0	14.0	10.0	13.0	13.0	10.0	12.0	11.0	10.0	9.0	8.0	8.0	8.0	8.0	7.0
	11	10	9	8	9	7	4	3	2	3	2	2	2	1	0	0	0	1	0	0	0	0	0	0
2- 3.......	8.0	9.0	11.0	9.0	9.0	11.0	9.0	7.5	6.5	5.0	6.0	3.0	5.0	4.5	4.0	9.0	5.5	4.0	6.0	8 0	12.0	14.0	15.0	18.0
	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5	8
3- 4.......	16.0	20.0	16.0	19.0	20.0	14.0	10.0	13.0	12.0	12.0	13.0	15.0	14.0	11.0	10.0	10.0	10.0	8.0	7.5	6.5	6.5	6.5	16.0	21.0
	6	8	7	6	7	1	0	1	2	0	3	4	2	0	0	0	0	0	0	0	0	0	7	8
4- 5.......	26.0	22.5	23.0	24.0	22.0	17.0	16.0	17.0	13.0	20.0	15.0	15.0	15.0	13.0	13.0	12.0	11.0	9.0	6	8.0	14.0	13.5	14.5	13.0
	9.4	8	6	10	6	7	7	7	3	7	5	5	3	3	5	2	0	0	0	0	1	2	2	4
5- 6.......	15.0	17.0	17.5	15.5	14.0	12.0	11.5	15 5	12.0	15.0	15.0	16.0	16.5	17.5	17.0	14.0	14.0	14.0	11.0	12.0	11.0	10.0	9.0	8.0
	4	7	7	5	2	1	0	1	2	5	4	8	6	8	6	3	5	2	0	1	2	0	0	0
6- 7.......	6.5	4.5	2.0	4.0	3.0	1.0	1.5	1.0	0.5	1.5	2.0	2.0	2.5	2.5	2.0	2.0	1.0	4.0	5.0	4.5	4.5	4.5	4.0	3.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7- 8.......	4.0	5.0	6.0	7.0	6.0	8.0	5.0	8.0	9.0	5.0	6.0	5.0	5.0	8.0	8.0	5.0	6.0	8.0	11.0	11.0	11.0	16.0	14.0	17.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	4	5
8- 9.......	14.0	11.0	9.0	11.0	14.0	10.0	5.0	3.0	5.0	5.0	13.0	18.0	19.0	17.0	16.0	14.0	13.0	13.0	13.0	15.0	14.0	14.0	13.0	12.0
	3	1	0	1	5	2	0	0	0	0	1	4	5	6	5	5	3	2	3	4	4	3	4	2
9-10.......	12.0	11.0	9.0	9.0	6.0	7.0	5.5	6.0	6.0	7.0	7.0	10.0	9.0	6.0	7.0	6.0	6.5	7.0	5.0	6.5	9.0	10.0	8.0	7.0
	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
10-11.......	8.0	7.0	6.0	6.0	6.0	7.0	6.0	4.0	4.0	6.0	5.0	5.0	6.0	4.0	2.0	1.0	1.0	1.0	1.0	1.0	2.0	5.0	4.0	4.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-12.......	4.0	4.0	6.0	3.0	3.5	3.5	6.5	8.5	10.0	11.0	8.0	7.0	8.0	9.0	9.0	8.0	10.0	12.0	15.0	16.0	16.0	21.0	21.0	20.0
	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	5	7	7	9	9	8
12-13.......	21.0	18.0	19.0	21.0	17.0	18.0	18.0	15.0	9.0	15.0	16.0	12.0	11.0	9.0	11.0	9.0	13.0	12.0	10.0	10.0	10 0	17.0	19.0	20.0
	9	8	8	8	8	8	7	6	2	3	6	5	2	0	1	1	3	3	0	0	1	7	9	9
13-14.......	21.0	17.0	14.0	16.0	16.0	14.0	9.0	6.0	4.0	7.0	6.0	6.0	8.0	5.0	4.0	2.5	3.5	6.0	3.0	2.0	5.0	3.0	3.0	4.0
	9	8	4	5	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-15.......	5.0	4.0	10.0	10.0	9.0	8.0	8.0	9.5	10.5	10.0	10.0	10.0	10.0	11.0	13.0	12.0	12.0	13.0	16.0	19.0	17.0	22.0	19.0	16.0
	0	0	0	0	0	1	0	0	0	1	0	1	0	3	3	5	3	4	5	6	8	9	8	9.0
15-16.......	21.0	19.0	16.0	16.0	13.0	21.0	24.0	29.0	34.0	37.0	31.0	31.0	30.0	27.0	33.0	28.0	24.0	25.0	27.0	29.0	30.0	33.0	27.0	21.0
	11.0	9	4	5	5	9	10	10	11	9	10	10	10	9.6	10	9.3	9	8.8	8	11	11	10	11	10
16-17.......	29.0	27.0	26.0	27.0	23.0	19.0	16.0	13.0	11.0	10.5	10.5	10.0	10.0	6.5	8.5	9.5	9.0	6.0	6.0	6.0	7.0	9.0	7.0	9.0
	11	11	10	11	9	9	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
17-18.......	11.0	15.0	18.0	17.0	18.0	17.0	15.0	17.0	14.0	16.0	14.0	15.0	18.0	17.0	18.0	20.0	21.0	25.0	31.0	34.0	33.0	35.0	41	43.0
	2	3	9	7	7	6	4	5	4	5	4	4	6	5	5	6	6	6	10	11	11	11	10.0	10
18-19.......	46.0	46.0	36.0	32.0	32.0	36.0	37.0	40.0	37.0	37.0	34.0	39.0	44.0	39.0	38.0	29.0	25.0	21.0	26.0	27.0	19.0	16.0	16	13.0
	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	9	8.8	8.6	6	10	8	4	4.0	4
19-20.......	16 0	16.0	16.0	17.0	14.0	11.0	9.0	8.0	4.0	4.0	6.0	7.0	8.0	12.0	11.0	11.0	11.0	9.0	11.0	12.0	11.0	14.0	17	14.0
	5	4	4	6	3	0	0	0	0	0	0	0	0	2	3	2	1	0	2	3	3	4	4.0	3
20-21.......	17.0	18.0	17.0	17.0	17.0	13.0	13.0	11.0	12.0	13.0	13.0	14.0	12.0	13.0	15.0	18.0	19 0	19.0	20.0	19.0	18.0	18.0	24	20.0
	7	7	7	7	6	5	2	1	1	3	4	4	3	3	5	6	7	8	8	8	8	6	10.0	8
21-22.......	18.0	20.0	19.0	13.0	10.0	11.0	10.0	12.0	10.0	19.0	29.0	30.0	23.0	20.0	21.0	24 0	22.0	20.0	21.0	23.0	23.0	20.0	19	18.0
	9	8	8	2	0	1	0	2	1	5	7	7	7	5	6	6	7	7	9	9	10	8	7.0	8
22-23.......	17.0	19.0	17.0	16.0	16.0	11.0	11.0	7.0	7.0	13..	16.0	31.0	17.0	4.5	9.5	3.0	8.0	14.0	13.0	4.0	4.0	8.0	10	10.0
	7	7	6	6	3	1	0	0	0	0	3	5	6	3	0	1	0	0	1	0	0	0	0.0	0
23-24.......	11.0	11.0	11.0	13.0	12.0	10.0	9.0	9.0	12.0	10.0	12.0	12.0	10.0	17.0	14.0	16.0	20.0	4.0	9.0	12 0	8.0	7.0	6.0	4.0
	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0
24-25.......	5.0	10.0	14.0	14.0	15.0	11.0	10.0	12.0	8.0	7.0	8.0	7.0	6.0	10.0	11 0	13.0	14.0	12.0	13.0	14.0	18.0	24.0	23.0	23.0
	0	2	1	1	4	0	1	3	0	0	0	0	0	0	0	1	5	2	3	4	4	9	9	9
25-26.......	27.0	23.0	22.0	20.0	19.0	17.0	13.0	12.0	12.0	16.0	18.0	24.0	25.0	22.0	13.0	17.0	20.0	19.0	26.0	30.0	25.0	21.0	17.0	19.0
	9.6	8.8	8	7.2	6.3	7	8	2	1	3	5	6	6	7	4	3	5	3	5	8	10	10	9	10
26-27.......	17.0	15.0	11.0	11.0	11.0	13.0	11.5	9.5	13.0	16 0	16.0	11.0	9.0	9.0	9.0	8.0	10.0	10.0	16.0	20.0	25.0	26.0	26.0	25.0
	5.2	3	0	0	0	1.4	0	0	1.4	4.5	4.5	0	0	0	0	0	0	0	4.5	7.2	8.8	9.4	9.4	8.8
27-28.......	25.0	24.0	22.0	22.0	26.0	28.0	19.0	17.0	14.0	19.0	20.0	17.0	14.0	16.0	13.0	15.0	11.0	9.0	9.0	11.0	8.0	5.0	6.0	6.0
	8.8	9	8	8	9.4	8.8	6.3	5.2	2.9	6.3	7.2	5.2	2.9	4.5	1.4	3	0	0	0	0	0	0	0	0
28-29.......	6.0	7.5	7.0	5.0	6.5	10.0	13.0	13.0	12.0	15.0	23.0	28.0	26.0	29 0	33.0	35.0	35.0	40.0	18.0	35.0	36.0	35.0	36.0	34.0
	0	0	0	0	0	0	1.4	1.4	1	3	8.8	9.3	9.4	9	10	10	10	10	6.1	10	10	10	8	9
29-30.......	41.0	38.0	30.0	32.0	28.0	34.0	30.0	33.0	32.0	35.0	32.0	31.0	29.0	29.0	28.0	27.0	25.0	26.0	26.0	28.0	36.0	30.0	27.0	24.0
	11	12	12	12	12	10	6	7	9	9	8	10	9	9	9.3	9.6	8.8	9.4	10	8	5	8	9.6	9
Totals ..	521.5 157.0	512.5 153.8	476.0 138.0	476.0 137.2	408.0 126.7	436.5 108.2	392.5 78.7	394.0 74.6	368.0 63.3	424.0 85.8	431.5 103.5	464.0 108.5	412.0 90.3	414.5 95.1	410.0 89.7	408.0 89.9	410.5 87.6	404.0 84.8	429.5 92.6	453.5 120.2	410.0 124.8	488.5 139.4	493.5 148.0	475.0 150.8

date stands express the number of times the tank was emptied during the hour given at the top of the column. In the lines of totals the first number gives the total miles of wind for that hour of the day during the whole month and the second number expresses the times the tank was emptied.

TABLE I.—Continued.—*Record of wind velocities and amount of water pumped by windmill on Physical Laboratory in May, 1897.*

Date.	Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	M.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
30–1……	23.0	21.0	17.0	17.0	14.0	11.0	9.0	6.0	5.0	5.5	9.0	13.0	17.0	17.0	23.0	24.0	24.0	24.0	26.0	29.0	30.0	25.0	27.0	28.0
	8.8	8.6	5.2	5.2	2.9	0	0	0	0	0	0	0	5.2	5.2	8.8	9	9	9	9.4	9	10	8.8	9.6	9.3
1–2……	29.0	26.0	27.0	27.0	23.0	21.0	20.0	23.0	25.0	22.0	26.0	23.0	24.0	24.0	22.0	19.0	18.0	18.0	20.0	25.0	21.0	20.0	20.0	20.0
	9	9.4	9.6	9.6	8.8	8.6	7.2	8.8	8.8	8	9.4	8.8	9	9	8	6.3	6.1	6.1	7.2	8.8	8.6	7.2	7.2	7.2
2–3……	26.0	23.0	21.0	20.0	21.0	18.0	18.0	25.0	27.0	30.0	24.0	23.0	24.0	24.0	21.0	22.0	28.0	28.0	29.0	30.0	30.0	29.0	29.0	27.0
	9.4	8.8	8.6	7.6	8.6	6.1	6.1	8.8	9.6	10	9	8.8	9	9	8.6	8	9.3	9.3	9	10.0	10	9	9	9.6
3–4……	19.0	17.0	15.0	15.0	13.0	6.0	5.0	7.0	11.0	10.0	9.0	9.0	8.0	5.0	1.5	2.0	3.0	2.5	3.5	3.0	2.0	3.0	4.0	2.0
	6.3	5.2	3	3	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4–5……	3.0	3.0	3.0	3.5	2.0	2.5	4.0	4.5	7.5	9.0	11.0	10.0	4.0	3.0	4.0	2.5	3.0	3.0	4.0	13.0	15.0	14.0	13.0	10.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	3	2.9	1.4	0
5–6……	8.0	10.0	12.0	12.0	11.0	11.0	10.0	11.0	11.0	11.0	11.0	10.0	4.0	3.0	4.0	3.0	3.0	4.0	4.0	5.0	7.0	5.0	7.0	9.0
	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6–7……	10.0	10.0	11.0	11.0	13.0	12.0	11.0	12.0	11.0	6.0	13.0	5.0	4.0	5.0	8.0	5.0	6.0	3.0	3.0	2.0	3.0	4.0	2.5	3.0
	0	0	0	0	1.4	1	0	1	0	0	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0
7–8……	5.0	6.0	11.0	12.0	10.0	11.0	10.0	8.0	7.0	7.0	7.0	6.0	4.0	4.0	3.0	4.0	4.0	3.0	6.0	9.0	8.0	12.0	17.0	20.0
	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5.2	7.2
8–9……	22.0	23.0	24.0	23.0	23.0	15.0	12.0	11.0	13.0	13.0	12.0	11.0	14.0	16.0	14.0	15.0	16.0	13.0	12.0	14.0	17.0	18.0	14.0	14.0
	8	8.8	9	8.8	8.8	3	1	0	1.4	1.4	1	0	2.9	4.5	2.9	3	4.5	1.4	1	2.9	5.2	6.1	2.9	2.9
9–10……	17.0	19.0	16.0	16.0	12.0	15.0	13.0	9.0	7.5	7.5	8.0	10.0	7.6	5.0	4.0	4.0	4.0	6.0	3.0	4.0	2.0	3.5	12.0	11.0
	5.2	6.3	4.5	4.5	1	3	1.4	0	0	0	0	0	0	0 0	0	0	0	0	0	0	0	0	1	0
10–11……	12.0	15.0	16.0	19.0	18.0	14.0	12.0	10.0	11.0	11.0	14.0	12.0	11.0	10.0	10.0	11.0	8.0	6.0	8.0	7.0	9.0	8.0	9.0	11.0
	1	3	4.5	6.3	6.1	2.9	1	0	0	0	2.9	4.5	0	0	0	0	0	0	0	0	0	0	0	0
11–12……	15.0	17.0	14.0	13.0	12.0	11.0	9.0	7.0	8.0	10.0	10.0	14.0	8.0	9.0	10.0	11.0	12.0	24.0	15.0	14.0	10.0	11.0	10.0	13.0
	3	5.2	2.9	1.4	1	0	0	0	0	0	0	2.9	0	0	0	0	1	9	3	2.9	0	0	0	1.4
12–13……	11.0	11.0	11.0	13.0	11.0	8.0	9.0	7.0	5.0	5.0	5.0	5.0	3.0	5.0	7	11.0	8.0	8.0	8.0	11.0	11.0	9.0	11.0	9.0
	0	0	0	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13–14……	10.0	14.0	15.0	11.0	12.0	9.0	12.0	18.0	18.0	17.0	16.0	18.0	20.0	23.0	19.0	19.0	18.0	20.0	19.0	18.0	18.0	18.0	15.0	14.0
	0	2.9	3	0	1	0	1	6.1	6.1	5.2	4.5	6.1	7.2	8.8	6.2	6.3	6.1	7.2	6.3	6.1	6.1	6.1	3	1.4
14–15……	15.0	19.0	16.0	15.0	13.0	7.0	7.0	15.0	12.0	13.0	9.0	2.0	3.0	2.0	3.0	5.0	10.0	7.0	8.0	7.0	8.0	7.0	6.0	3.0
	3	6.3	4.5	3	1.4	0	0	3	1	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15–16……	2.0	4.0	4.0	7.0	5.0	4.0	5.0	4.0	5.0	5.0	6.0	6.0	4.5	1.5	3.0	3.0	2.5	4.0	3.5	2.5	3.0	4.0	6.0	5.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16–17……	8.0	8.0	8.0	7.0	3.5	4.5	9.0	10.0	12.0	14.0	13.0	12.0	13.0	15.0	17.0	15.0	16.0	13.0	9.0	9.0	9.0	9.0	9.0	8.0
	0	0	0	0	0	0	0	0	1	2.9	1.4	1	1.4	3	5.2	3	4.5	1.4	0	0	0	0	0	0
17–18……	5.5	4.5	7.0	7.0	9.0	7.0	10.0	10.0	10.0	13.0	15.0	14.0	17.0	14.0	9.0	10.0	6.0	5.0	6.0	9.0	8.0	9.0	5.0	4.0
	0	0	0	0	0	0	0	0	0	1.4	3	2.9	5.2	2.9	0	0	0	0	0	0	0	0	0	0
18–19……	7.0	10.0	10.0	11.0	11.0	10.0	10.0	12.0	12.0	13.0	14.0	10.0	15.0	9.0	6.0	4.0	9.0	15.0	17.0	16.0	14.0	13.0	19.0	15.0
	0	0	0	0	0	0	0	1	1	1.4	2.9	0	3	0	0	0	0	3	5.2	4.5	2.9	1.4	6.3	3
19–20……	22.0	22.0	23.0	24.0	22.0	17.0	14.0	19.0	19.0	25.0	23.0	22.0	20.0	18.0	15.0	12.0	16.0	14.0	12.0	16.0	14.0	15.0	15.0	16.0
	10	11	10	9	9	7	5	8	7	11	10	9	9	8	6	4	7	5	4	4	5	4	4	5
20–21……	20.0	23.0	26.0	25.0	23.0	24.0	28.0	30.0	28.0	24.0	21.0	20.0	17.0	19.0	16.0	16.0	14.0	13.0	12.0	8.0	8.0	8.0	7.0	6.0
	9	11	11	9	10	11	10	10	10	10	10	8	5	7	6	5	4	0	0	0	0	0	0	0
21–22……	4.0	5.0	4.0	6.0	7.0	6.0	8.0	5.0	5.0	7.0	8.0	9.0	8.0	8.0	9.0	9.0	10.0	9.0	8.0	16.0	21.0	18.0	18.0	22.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	10	8	7	10
22–23……	23.0	20.0	18.0	15.0	12.0	14.0	13.0	14.0	19.0	10.0	14.0	10.0	10.0	8.0	10.0	10.0	18.0	17.0	17.0	18.0	21.0	28.0	38.0	34.0
	11	9	8	4	3	5	1	5	7	0	7	4	0	0	0	2	7	6	3	7	11	10	10	9
23–24……	30.0	30.0	22.0	25.0	26.0	21.0	18.0	19.0	20.0	21.0	16.0	16.0	17.0	15.0	16.0	19.0	20.0	16.0	22.0	19.0	18.0	17.0	13.0	12.0
	9	9	9	8	8	9	7	9	8	9	6	6	6	7	5	9	8	6	9	9	9	9	3	2
24–25……	10.0	6.0	8.0	12.0	12.0	10.0	9.0	10.0	6.0	3.0	4.0	4.0	5.0	4.0	5.0	6.0	3.0	3.0	5.0	4.0	3.0	3.0	4.0	5.0
	2	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25–26……	8.0	6.0	6.0	5.0	6.0	6.0	7.0	13.0	12.0	11.0	8.0	8.0	9.0	4.0	4.0	5.0	6.0	4.0	7.0	6.0	10.0	11.0	13.0	12.0
	0	0	0	0	0	0	1	2	3	2	0	0	0	0	0	0	0	0	0	0	0	0	1.4	1
26–27……	14.0	11.0	13.0	14.0	13.0	10.0	10.0	11.0	11.0	9.0	8.0	7.0	7.0	8.0	6.0	7.0	7.0	5.0	7.0	8.0	10.0	14.0	13.0	13.0
	2.9	2.9	1.4	2.9	1.4	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2.9	1.4	1.4
27–28……	10.0	8.0	8.0	8.0	6.0	4.0	3.0	4.0	4.0	7.0	10.0	15.0	21.0	27.0	26.0	28.0	27.0	26.0	26.0	25.0	23.0	24.0	31.0	26.0
	0	0	0	0	0	0	0	0	0	0	1	4	6	7	7	7	7	9.4	9.4	8	9	11	12	9
28–29……	22.0	20.0	16.0	17.0	18.0	18.0	15.0	11.0	13.0	12.0	7.0	6.0	6.0	4.0	4.0	5.0	6.0	9.0	9.0	10.0	14.0	16.0	15.0	14.0
	3	1	5	6	7	8	5	0	2	2	0	0	0	0	0	0	0	0	0	2	3	5	3	4
29–30……	17.0	16.0	15.0	13.0	11.0	14.0	7.0	6.0	13.0	13.0	11.0	20.0	17.0	16.0	16.0	14.0	15.0	22.0	19.0	21.0	19.0	23.0	23.0	14.0
	5	5	6	5	2	5	0	0	3	3	2	6	5	4	5	3	4	6	8	9	9	10	10	6
30–31……	19.0	23.0	20.0	22.0	19.0	20.0	19.0	15.0	13.0	12.0	13.0	12.0	10.0	9.0	9.0	10.0	7.0	9.0	11.0	11.0	11.0	11.0	10.0	10.0
	10	9	10	8	9	8	5	2	0	0	3	1	0	0	0	0	0	0	2	0	0	0	0	0
Totals…	446.5 115.6	453.5 122.4	437.0 116.2	440.5 106.3	411.5 93.8	361.0 77.6	346.0 52.7	366.5 66.7	378.0 68.9	373.0 68.7	375.0 74.5	367.0 72.5	342.0 73.9	334.5 75.4	324.5 68.8	329.5 65.6	347.5 77.5	353.5 78.8	356.0 76.5	389.5 89.6	397.0 104.8	409.5 102.4	435.5 96.4	410.0 89.4

TABLE I.—Continued.—*Record of wind velocities and water pumped by windmill on Physical Laboratory during June, 1897.*

Date.	Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	M.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
31—1	11.0	11.0	12.0	11.0	13.0	10.0	16.0	21.0	20.0	17.0	12.0	17.0	17.0	18.0	16.0	12.0	10.0	6.0	6.0	7.0	7.0	7.0	8.0	9.0
	0	0	0	0	0	0	4	7	9	6	2	8	8	7	3	1	0	0	0	0	0	0	0	0
1—2	8.0	10.0	12.0	11.0	12.0	16.0	9.0	11.0	11.0	11.0	12.0	15.0	14.0	12.0	14.0	14.0	13.0	12.0	13.0	18.0	15.0	14.0	13.0	13.0
	3	3	3	4	2	0	1	2	0	0	0	0	0	0	0	0	0	2	2	4	4	3	4	2
2—3	14.0	12.0	12.0	15.0	21.0	18.0	17.0	15.0	13.0	15.0	13.0	15.0	13.0	10.0	10.0	10.0	11.0	14.0	11.0	14.0	16.0	15.0	16.0	19.0
	4	2	1	3	8.6	5	8	5	5	4	6	6	3	2	0	1	2	3	3	6	9	8	9	9
3—4	20.0	20.0	17.0	17.0	14.0	11.0	11.0	14.0	12.0	13.0	10.0	11.0	15.0	11.0	14.0	13.0	11.0	12.0	17.0	18.0	21.0	20.0	21.0	18.0
	10	10	9	8	5	4	3	5	4	4	3	3	4	4	4	5	2	4	8	10	11	10	10	8
4—5	16.0	18.0	15.0	16.0	8.0	10.0	11.0	12.0	13.0	14.0	14.0	14.0	14.0	9.0	14.0	13.0	16.0	14.0	11.0	7.0	5.0	3.0	2.5	4.5
	9	9	7	7	0	0	1	1	4	5	4	4	3	2	4	4	4	3	0	0	0	0	0	0
5—6	6.0	5.5	4.5	9.0	15.0	16.0	15.0	15.0	15.0	22.0	15.0	10.0	14.0	12.0	12.0	10.0	13.0	10.0	8.0	9.0	6.0	8.0	6.0	7.0
	0	0	0	2	4	5	5	5	7	6	7	0	5	1	1	0	3	0	0	0	0	0	0	0
6—7	8.0	8.0	9.0	11.0	10.0	10.0	11.0	11.0	11.0	3.0	3.0	2.5	5.5	4.0	3.0	6.0	3.5	5.5	3.0	9.0	8.0	7.0	6.0	5.0
	1	1	1	1	2	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
7—8	6.0	4.0	8.0	6.0	4.0	3.5	3.5	3.0	2.0	2.5	2.0	2.5	4.0	3.0	2.0	2.0	2.5	4.0	5.0	6.0	11.0	13.0	12.0	11.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	4	4
8—9	13.0	13.0	11.0	10.0	9.0	9.0	11.0	8.0	7.0	6.0	6.0	4.0	7.0	7.0	6.0	5.0	6.0	7.0	9.0	9.0	8.0	10.0	12.0	13.0
	4	4	3	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	3	4
9—10	16.0	20.0	19.0	10.0	6.0	4.0	10.0	9.0	8.0	10.0	10.0	8.0	9.0	9.0	10.0	7.0	7.0	10.0	11.0	13.0	14.0	18.0	16.0	16.0
	7	9	6	0	0	0	0	1	0	1	1	0	0	1	0	0	0	1	1	3	4	7	6	5
10—11	20.0	19.0	18.0	16.0	13.0	11.0	8.0	14.0	11.0	10.0	9.0	13.0	20.0	15.0	10.0	10.0	6.0	11.0	15.0	19.0	17.0	16.0	14.0	9.0
	9	9	8	6	4	2	1	4	1	0	1	2	6	4	2	1	0	1	4	9	8	5	4	1
11—12	7.0	6.0	6.0	8.0	7.0	7.0	6.0	6.0	6.0	5.5	4.5	3.0	5.0	5.0	5.0	5.0	5.0	2.0	4.0	4.0	3.0	5.0	9.0	10.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
12—13	11.0	12.0	11.0	11.0	13.0	12.0	9.0	11.0	11.0	17.0	14.0	15.0	10.0	16.0	15.0	15.0	13.0	15.0	16.0	17.0	14.0	11.0	10.0	8.0
	3	3	1	2	4	3	0	1	3	5	4	3	0	4.5	2	3	1.4	3	10	4	2	0	0	0
13—14	11.0	12.0	8.0	8.0	7.0	7.0	7.0	11.0	12.0	10.0	8.0	5.0	5.0	4.0	2.5	3.5	7.0	3.0	3.0	6.0	12.0	11.0	11.0	8.0
	1	1	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0
14—15	10.0	8.0	8.0	6.0	7.0	5.0	5.0	7.0	8.0	6.0	8.0	8.0	9.0	10.0	8.0	5.0	2.5	3.5	6.0	7.0	5.0	9.0	11.0	12.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
15—16	11.0	15.0	16.0	15.0	12.0	12.0	7.0	7.0	10.0	8.0	7.0	6.0	6.0	5.0	8.0	7.0	9.0	7.0	6.0	5.0	7.0	8.0	7.0	9.0
	1.4	3	4.5	3	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
16—17	10.0	9.0	10.0	20.0	17.0	9.0	9.0	9.0	10.0	20.0	8.0	6.0	7.0	9.0	14.0	17.0	12.0	15.0	16.0	20.0	21.0	14.0	5.5	7.5
	0	0	0	7.2	5.2	0	0	0	2	2	0	0	0	0	0	0	0	3	6	9	8	2	0	0
17—18	14.0	14.0	6.0	7.0	7.0	12.0	15.0	20.0	21.0	14.0	12.0	17.0	17.0	16.0	15.0	13.0	15.0	16.0	12.0	36.0	7.0	8.0	12.0	15.0
	3	1	0	0	0	0	5	6	9	3	1	7	3	4.5	3	1.4	3	4	7	9	0	0	3	3
18—19	9.0	9.0	4.0	6.0	7.0	10.0	11.0	8.0	8.0	7.0	6.0	5.0	7.0	5.0	9.0	11.0	11.0	10.0	13.0	38.0	20.0	15.0	10.0	8.0
	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	1	0	0	4	11	8	4	0	0
19—20	9.0	10.0	8.0	6.0	7.0	5.0	4.0	5.0	5.0	10.0	17.0	10.0	5.0	5.0	9.0	10.0	10.0	13.0	16.0	10.0	15.0	11.0	10.0	9.0
	0	1	0	0	0	0	0	0	0	4	6	3	0	0	1	2	2	3	6	1	6	3	2	0
20—21	7.0	10.0	7.0	7.0	8.0	5.0	7.0	6.0	7.0	8.0	10.0	10.0	10.0	8.0	6.0	7.0	6.0	4.0	7.0	11.0	12.0	12.0	10.0	8.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	1
21—22	7.0	9.0	10.0	7.0	7.0	10.0	10.0	7.0	8.0	8.0	8.0	8.0	10.0	10.0	12.0	14.0	12.0	12.0	16.0	16.0	20.0	13.0	7.0	7.0
	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	1	4	1	2	1	2	0
22—23	12.0	18.0	16.0	17.0	17.0	13.0	13.0	9.0	7.0	7.0	4.0	3.0	7.0	13.0	10.0	13.0	10.0	6.0	3.0	3.0	3.0	7.0	9.0	15.0
	4	8	7	8	6	3	2	0	0	0	0	0	0	3	1	4	0	0	0	0	0	0	0	4
23—24	12.0	10.0	8.0	6.0	15.0	13.0	17.0	7.0	7.0	6.0	4.0	2.0	4.0	4.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0
	1	0	0	0	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24—25	3.0	3.0	2.0	2.0	3.0	8.0	5.0	3.0	6.0	10.0	7.0	8.0	13.0	12.0	12.0	10.0	10.0	13.0	10.0	4.0	3.0	2.0	2.5	3.0
	0	0	0	0	0	0	0	0	0	1	0	0	3	2	3	0	1	2	1	0	0	0	0	0
25—26	4.0	5.0	5.0	11.0	12.0	12.0	10.0	10.0	8.0	7.0	6.0	6.0	7.0	7.0	8.0	8.0	8.0	6.0	8.0	10.0	10.0	9.0	9.0	9.0
	0	0	1	1	4	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	1	1	1	0
26—27	7.0	8.0	7.0	6.0	9.0	12.0	13.0	11.0	9.0	8.0	7.0	4.0	5.0	4.0	4.0	6.0	7.0	8.0	8.0	6.0	7.0	6.0	5.0	7.0
	0	0	0	0	1	3	4	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
27—28	8.0	8.0	8.0	9.0	9.0	8.0	7.0	7.0	10.0	9.0	10.0	10.0	6.0	8.0	7.0	6.0	7.0	11.0	11.0	10.0	12.0	12.0	13.0	13.0
	1	0	1	1	0	0	0	0	2	1	1	0	0	0	1	0	0	2	3	1	2	2	3	4
28—29	13.0	14.0	17.0	18.0	15.0	13.0	13.0	11.0	9.0	20.0	14.0	15.0	15.0	8.0	10.0	10.0	8.0	10.0	14.0	14.0	17.0	18.0	15.0	15.0
	3	5	7	5	3	4	3	4	2	9	2	8	4	0	2	0	0	2	3	4	6	7	7	5
29—30	15.0	16.0	16.0	18.0	16.0	14.0	7.0	4.5	4.5	6.0	7.0	12.0	12.0	10.0	10.0	9.0	7.0	6.0	7.0	4.5	3.5	4.0	6.0	6.0
	9	8	9	8	7	3	0	0	0	0	0	3	1	1	0	0	0	0	0	0	0	0	0	0
Totals	320.0 73.4	326.5 78.0	310.5 67.5	320.0 66.2	320.0 61.8	305.5 38.0	300.5 44.0	292.5 48.0	299.5 51.0	310.0 51.0	267.5 38.0	267.0 47.0	292.5 40.0	269.0 36.0	278.5 29.0	275.5 27.4	261.5 20.4	269.0 35.0	281.0 63.0	353.5 76.0	322.5 80.0	310.0 63.0	291.5 58.0	297.0 51.0

TABLE I.—Continued.—*Record of wind velocities and water pumped by windmill on Physical Laboratory during July, 1897.*

Date.	Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	M.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
30—1	6.0	6.0	10.0	10.0	9.0	5.0	3.0	5.0	7.0	5.0	3.0	4.0	5.0	4.0	5.0	5.0	5.5	3.5	3.0	3.0	2.0	4.0	5.0	6.0
	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1—2	7.0	7.0	4.0	7.0	9.0	7.0	3.0	4.0	5.0	7.0	7.0	4.0	6.0	5.0	5.0	5.0	3.5	3.0	5.0	2.0	6.0	7.0	9.0	12.0
	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3
2—3	11.0	11.0	12.0	8.0	8.0	7.0	12.0	12.0	11.0	10.0	10.0	8.0	12.0	15.0	17.0	14.0	12.0	12.0	16.0	21.0	24.0	22.0	20.0	20.0
	2	1	2	0	0	1	2	1	0	0	0	0	2	4	4	4	0	0	5	10	10	10	9	8
3—4	25.0	26.0	27.0	25.0	23.0	19.0	19.0	17.0	20.0	21.0	23.0	20.0	18.0	16.0	17.0	13.0	14.0	15.0	15.0	13.0	14.0	15.0	15.0	16.0
	11	11	11	10	10	9	8	8	9	10	9	10	8	4	8	2	3	3	4	1	0	3	3	4.5
4—5	15.0	14.0	16.0	10.0	11.0	12.0	7.0	4.0	5.0	5.0	2.0	7.0	12.0	11.0	10.0	6.0	4.0	6.0	7.0	6.0	3.0	2.0	3.0	4.0
	7	6	6	6	8	5	0	0	0	0	0	1	5	1	0	0	0	0	0	0	0	0	0	0
5—6	4.0	5.0	4.0	5.0	5.0	7.0	7.0	5.0	6.0	7.0	7.0	7.0	6.0	6.0	10.0	4.0	4.0	1.0	4.0	8.0	10.0	12.0	13.0	15.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	5
6—7	15.0	15.0	16.0	16.0	14.0	13.0	8.0	6.0	6.0	6.0	7.0	6.0	7.0	4.0	6.0	3.0	2.0	3.5	7.0	9.0	8.0	6.0	9.0	13.0
	3	3	4.5	4.5	2.9	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4
7—8	15.0	14.0	10.0	9.0	7.0	6.0	7.0	7.0	6.0	6.0	6.0	6.0	7.0	7.0	4.0	10.0	9.0	4.0	7.0	6.0	4.0	4.0	4.0	5.0
	3	2.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8—9	8.0	9.0	11.0	12.0	11.0	9.0	6.0	5.0	6.0	2.5	4.5	8	9.0	3.0	2.0	6.0	1.0	5.0	4.0	2.0	3.0	11.0	11.0	7.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9—10	8.0	14.0	12.0	10.0	9.0	7.0	12.0	10.0	5.0	5.0	4.5	5.5	5.0	5.0	4.0	7.0	3.5	4.5	5.5	5.5	5.0	4.0	5.0	3.0
	0	2.9	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10—11	2.0	5.0	6.0	11.0	9.0	15.0	26.0	24.0	25.0	34.0	26.0	23.0	19.0	19.0	15.0	12.0	14.0	12.0	15.0	14.0	13.0	11.0	11.0	11.9
	0	0	0	0	0	3	9.4	9	8.8	10	9.4	8.8	6.3	6.3	3	1	2.9	1	3	2.9	1.4	0	0	0
11—12	12.0	10.0	6.5	6.5	9.0	21.0	9.0	9.5	8.5	14.0	14.0	15.0	16.0	14.0	14.0	16.0	18.0	18.0	16.0	15.0	16.0	15.0	17.0	18.0
	1	0	0	0	0	8.6	0	0	0	2.9	2.9	3	4.5	2.9	2.9	4.5	6.1	6.1	4.5	3	4.5	3	5.2	6.1
12—13	20.0	18.0	19.0	22.0	13.0	12.0	13.0	10.0	10.0	11.0	12.0	13.0	13.0	15.0	17.0	16.0	15.0	15.0	14.0	15.0	14.0	13.0	18.0	17.0
	7.2	6.1	6.3	8	1.4	1	1.4	0	0	0	1	1.4	1.4	3	5.2	4.5	3	3	2.9	3	2.9	1.4	6.1	5.2
13—14	16.0	18.0	12.0	13.0	11.0	8.0	6.0	3.5	4.5	6.0	7.0	6.0	4.0	4.0	1.0	2.0	3.0	4.0	4.0	6.0	9.0	11.0	10.5	10.5
	4.5	6.1	1	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14—15	12.0	10.0	9.0	8.5	6.0	4.5	4.5	8.0	7.0	9.0	7.0	4.0	3.5	3.5	5.0	5.5	6.5	6.0	3.0	7.0	5.5	3.5	4.0	6.0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15—16	6.0	7.0	6.0	5.0	4.0	4.0	5.0	6.0	6.5	4.5	5.0	3.0	3.0	3.5	3.5	4.0	3.0	2.0	3.0	4.0	6.0	8.0	9.0	7.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16—17	9.0	6.0	5.0	6.0	5.0	4.0	4.5	5.5	4.0	6.0	6.0	6.0	5.0	0.0	1.5	2.5	3.5	2.5	3.5	1.0	3.5	3.5	5.0	2.5
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17—18	6.0	5.0	7.0	5.0	4.0	4.0	6.0	7.0	8.0	6.0	5.0	3.0	4.0	5.0	2.0	1.0	3.0	2.0	0.0	1.0	2.0	5.0	3.5	3.5
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18—19	8.0	10.0	10.0	10.0	8.5	6.5	6.0	6.0	8.0	8.0	3.0	3.0	5.0	2.0	1.0	1.0	2.0	3.0	4.0	5.0	3.0	4.0	3.0	3.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19—20	6.0	5.5	4.5	5.0	5.0	7.0	8.0	8.0	6.5	7.5	6.0	6.0	6.0	4.0	2.5	3.5	2.0	4.0	4.0	5.0	7.0	9.0	11.0	11.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20—21	10.0	9.0	13.0	18.0	18.0	15.0	12.0	10.0	13.0	11.0	10.0	7.5	8.0	9.0	11.0	10.0	11.0	10.0	13.0	14.0	19.0	25.0	28.0	27.0
	0	0	1.4	6.1	6.1	3	1	0	1.4	0	0	0	0	0	0	0	0	0	1.4	2.9	6.3	8.8	9.3	9.6
21—22	30.0	30.0	30.0	33.0	30.0	24.0	16.0	11.0	14.0	15.0	16.0	16.0	13.0	18.0	14.0	14.0	15.0	14.0	13.0	17.0	16.0	18.0	20.0	19.0
	10	10	10	10	10	9	4.5	0	2.9	3	4.5	4.5	1.4	6.1	2.9	2.9	3	2.9	1.4	5.2	4.5	6.1	7.2	6.3
22—23	22.0	21.0	19.0	24.0	20.0	18.0	15.0	13.0	8.0	7.0	7.0	7.0	7.0	8.5	9.5	10.0	10.0	12.0	9.0	9.0	7.0	5.0	5.0	5.0
	8	8.6	6.3	9	7.2	6.1	3	1.4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
23—24	6.0	6.0	6.0	5.5	7.5	7.0	2.5	1.5	4.5	3.5	3.0	1.0	4.0	7.0	5.0	4.0	2.0	3.0	4.5	2.0	2.5	3.5	5.5	6.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24—25	6.0	3.0	4.0	4.0	3.0	1.0	2.0	8.0	10.0	8.0	6.0	6.0	4.0	3.0	4.0	4.0	6.5	5.5	7.0	7.0	10.0	9.0	9.0	7.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25—26	10.0	11.0	14.0	9.0	8.0	5.0	10.0	9.5	9.5	10.0	9.5	3.0	1.0	4.0	0.0	2.0	8.0	14.0	16.0	19.0	18.0	21.0	22.0	23.0
	0	0	2.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.9	4.5	6.3	6.1	8.6	8	8.8
26—27	21.0	22.0	21.0	23.0	22.0	20.0	15.5	15.5	13.0	12.0	13.0	8.0	7.0	9.0	9.0	11.0	8.0	10.0	12.0	15.0	13.0	15.0	19.0	18.0
	8.6	8	8.6	8.8	8	7.2	3	3	1.4	1	1.4	0	0	0	0	0	0	0	1	3	1.4	3	6.3	6.1
27—28	23.0	18.0	16.0	14.0	14.0	14.0	13.0	10.0	10.0	11.0	11.0	7.0	6.0	7.0	4.0	5.0	3.0	2.0	4.0	5.0	5.0	9.0	10.0	7.0
	8.8	6.1	4.5	2.9	2.9	2.9	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28—29	8.0	8.0	6.0	3.5	2.5	2.0	5.0	3.5	5.5	6.0	3.5	2.5	5.0	3.5	2.5	2.5	3.0	1.5	2.0	1.5	1.0	3.5	5.0	5.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29—30	4.5	2.5	1.5	4.5	10.0	10.0	1.0	5.0	7.0	9.0	12.0	11.0	12.0	11.0	10.0	8.0	8.0	8.0	2.0	3.0	3.5	3.0	3.5	3.0
	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
30—31	3.5	5.5	10.0	9.0	10.0	12.0	9.0	3.5	3.0	3.5	2.0	2.0	4.0	4.0	4.0	4.0	5.0	12.0	4.5	6.5	5.0	4.0	3.0	6.0
	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Totals	328.0 75.1	351.5 71.7	347.5 64.5	351.5 67.7	325.5 57.5	306.0 58.2	273.0 34.7	253.0 22.4	261.5 23.5	276.5 26.0	258.0 29.2	228.9 25.7	236.5 29.6	220.0 27.3	215.5 27.0	211.0 18.9	208.0 18.0	218.0 21.9	227.0 27.7	247.5 37.3	258.0 37.1	286.0 47.9	311.0 60.1	319.5 64.0

ABLE I.—Continued.—*Record of wind velocities and water pumped by wind mill on Physical Laboratory during August, 1897.*

Date.	Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	M.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
31– 1......	16.0	10.0	7.0	6.0	8.0	9.0	9.0	11.0	9.0	8.0	9.0	8.0	10.0	5.0	4.0	5.0	5.0	9.0	9.0	5.0	4.0	3.0	4.0	8.0
	4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1– 2......	9.0	7.0	7.0	8.0	10.0	12.0	12.0	11.0	9.0	4.0	6.0	5.0	5.5	3.0	3.5	3.5	3.5	3 0	4.0	3.0	6.0	6.0	6.0	4.0
	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2– 3......	12.0	5.0	9.0	4.0	5.0	4.0	4.0	2.0	3.5	3.5	2.0	1.0	4.0	4.0	7.0	5.0	8.0	11.0	11.0	10.0	12.0	12.0	9.0	6.0
	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	3	0	0
3– 4......	8.0	10.0	10.0	10.0	10.0	10.0	8.0	10.0	10.0	7.0	8.0	8 0	9.0	10.0	7.0	17.0	17.0	14.0	11.0	15.0	16.0	12.0	11.0	11.0
	0	0	0	0	1	0	0	2	0	0	1	0	1	0	0	5.2	5.2	3	0	4	3	3	1	2
4– 5......	15.0	15.0	16.0	16.0	14.0	13.0	11.0	11.0	9.0	8.0	4.0	4.0	3.0	4.0	3.0	9.0	12.0	10.0	9.0	9.0	10.0	12.0	12.0	12.0
	4	6	7	6	4	4	1	2	0	0	0	0	0	0	0	1	2	1	0	1	1	1	3	3
5– 6......	11.0	11.0	12.0	10.0	10.0	11.0	8.0	7.0	6.0	3.0	2.0	0 0	2.0	4.0	2.0	3.0	4.0	4.0	5.0	5.0	4.0	4.0	4.0	5.0
	1	1	3	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6– 7......	5.0	4.0	6.0	5.0	6.0	8.0	7.0	6.0	4.5	3.5	5.0	6.0	7.0	5.0	5.0	4.0	5.0	2.5	2.0	1.0	1.5	3.5	7.0	5.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7– 8......	8.0	10.0	14.0	11.0	10.0	7.0	8.0	6.0	6.0	4.0	3.0	5 0	6.0	6.0	6.0	3.0	3.0	3.0	4.0	7.0	6.5	7.5	10.0	9.0
	0	0	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
8– 9......	8.0	9.0	6.0	6.0	9 0	7.0	5.0	0.0	1.0	1.0	1.0	6.0	6.0	8.0	8.0	9.0	13.0	5.0	12.0	9.0	5.0	2.0	6.0	7.0
	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	2	1	0	0	1	0
9–10......	10.0	15.0	16.0	18.0	15.0	12.0	11.0	11.0	11.0	9.0	9.0	10.0	11.0	11.0	13.0	14.0	13.0	13.0	16.0	20.0	16.0	16.0	11.0	10.0
	3	6	6	6	5	2	2	1	2	1	0	2	1	2	5	4	5	5	6	7	6	5	3	1
10–11......	11.0	13.0	14.0	15.0	17.0	16.0	15.0	14.0	14.0	14.0	13.0	13.0	13.0	11.0	12.0	11.0	11.0	9.0	10.0	7.0	7.0	8.0	8.0	9.0
	2	4	5	6	6	6	5	5	5	5	4	4	4	2	3	2	2	0	0	0	0	0	0	0
11–12......	12.0	14.0	11 0	12.0	13.0	12.0	9.0	5.0	8.0	11.0	11 0	11.0	9.0	8.0	6.0	6.0	6.0	5.0	7.0	3.0	1.0	3.5	3.5	4.0
	1	2.9	0	1	1.4	3	0	0	0	2	4	2	0	0	0	0	0	0	0	0	0	0	0	0
12–13......	3.0	3.0	4.0	2.0	3.0	2 0	3.0	0.0	2.5	9.0	9.0	9.0	11.0	10.0	4.0	8.0	12.0	10.0	11.0	10.0	15.0	20.0	17.0	18.0
	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	3	1	1	2	5	6	6	7
13–14......	16.0	19.0	19.0	18.0	15.0	13.0	10.0	11.0	10.0	8.0	9.0	13.0	15.0	15.0	12.0	10.0	11.5	8.5	8.0	9.0	12.0	11.0	14.0	15.0
	6	6	6	6	4	5	0	1	0	0	1	4	5	5	2	2	3	1	0	0	3	2	5	5
14–15......	18.0	22.0	21.0	19.0	17.0	14.0	10.0	12.0	14.0	15.5	17.0	13.0	17.0	16.0	15.0	14.0	9.0	15 0	16.0	20.0	22.0	20.0	21.0	20.0
	6	6	6	7	5	5	1	4	5	5	6	4	5	5	5	3	1	5	4	7	9	11	10	10
15–16......	23.0	22.0	24.0	24.0	20.0	22.0	18.0	23.0	22.0	22.0	19.0	19.0	16.0	15.0	15.0	16.0	18.0	18.0	18.0	17.0	15 0	13.0	14.0	13.0
	8	9	7	8	8	6	3	6	9	6	5	6	3	4	3	4	5	6	5	6	5	3	4	3
16–17......	14.0	15.0	13.0	16.0	14.0	14.0	11.0	9.0	8.0	11.0	9.0	9.0	10.0	8.0	6.0	5.0	7.0	5.0	4.0	2.0	3.0	3.0	4.0	5.0
	4	4	4	4	5	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17–18......	6.0	5.0	9.0	10.0	11 0	13.0	14.0	13.0	10.0	9.0	10.0	11.0	12.0	10.0	12.0	12.0	10.0	7.0	9.0	8.0	9 0	14.0	13.0	14.0
	0	0	0	0	0	3	3	2	0	0	1	3	2	1	3	3	0	0	0	0	1	4	3	3
18–19......	17.0	14.0	14.0	16.0	7.0	8.0	10.0	10.5	7.5	18.0	17.0	15.0	15.0	13.0	11.0	14.0	14.0	15.0	16.0	14.0	14.0	11.0	10.0	7.0
	6	4	4	5	0	1	1	2	0	5	5	5	5	2	4	4	5	3	6	6	2	1	2	0
19–20......	7.0	7.0	7.0	10.0	11.0	8.0	7.0	5.0	3.0	7.0	7 0	4.0	5.0	4.0	3.0	2.0	3.0	3 0	6.0	5.0	6.0	7.0	7.0	5.0
	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20–21......	5.0	4.0	5.0	6.0	5.0	4.0	4.0	5.0	1.0	0.0	1.0	0.0	1.0	2.0	1.0	0.0	4.0	5.0	3.0	2.0	6.0	6.0	6.0	4.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21–22......	5.0	5.0	3.0	3.0	2.0	6.0	6.0	4.0	2.0	0.0	1.0	1.0	2.0	1.0	3.0	1.0	2.0	3.0	4.0	0.0	5.0	7.0	10.0	5.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22–23......	8.0	12.0	13.0	18.0	19.0	16.0	14.0	13.0	13.0	10.0	10.0	7.0	6.0	6.0	5.0	7.0	5.0	5.0	3.0	4.0	3.0	3.0	3.0	3.0
	1	3	4	6	6	5	5	3	4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
23–24......	6.0	5.0	4.0	4.0	2.0	2.0	5.0	4.0	4.0	6.0	7.0	8.0	4.0	6.0	6.0	5.0	9.0	14.0	15.0	13.0	13.0	14.0	14.0	15.0
	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	3	3	5	2	4	4	4	4
24–25......	16.0	16.0	16.0	15.0	13.0	13.0	12.0	8.0	10.0	14.0	12.0	10.0	10.0	4.0	5.0	6.0	3.0	4.0	5.0	5.0	3.0	2.0	3.0	4.0
	6	5	6	4	4	3	3	0	0	4	2	2	1	0	0	0	0	0	0	0	0	0	0	0
25–26......	4.0	5.0	5.0	5.0	3.0	2.0	5.0	5.0	7.0	10.0	9.0	9.0	10.0	10.0	10.0	12.0	12.0	12.0	12.0	14.0	11.0	17.0	20.0	24.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	6	9
26–27......	27.0	22.0	21.0	17.0	13.0	10.0	18.0	16.0	15.0	13.0	12.0	11.0	12.0	7.0	9.0	10.0	10.0	8.0	9.0	9.0	9.0	11.0	11.0	13.0
	11	11	10	7	3	2	6	5	4	3	3	2	1	0	0	1	0	0	0	0	0	0	0	1.4
27–28......	12.0	13.0	14.0	13.0	12.0	8.0	5.0	2.0	1.0	1.0	4.0	5 0	1.0	1.0	2.0	4.0	8.0	7.0	5.0	7.0	8.0	11.0	15 0	15.0
	1	1.4	2.9	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
28–29......	16.0	11.0	10.0	12.0	8.0	3.0	2.0	4.0	5.0	7.0	10.0	10.0	17.0	13.0	16.0	17.0	18.0	18.0	20.0	17.0	20.0	22.0	21.0	19 0
	4.5	0	0	1	2	0	0	0	0	0	1	1	5	4	5	6	6	3	5	5	7	9	10	8
29–30......	20.0	23.0	21.0	19.0	17.0	18.0	15.0	12.0	12.0	11.0	9.0	10.0	9.0	8.0	8.0	10.0	9.0	5.0	6.0	5.0	4.0	4.0	4.0	6.0
	6	8	7	5	5	6	4	2	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30–31......	6.0	6.0	7.0	6.0	7.0	8.0	6.0	5.0	3.0	2.0	2.0	1.0	2.0	4.0	1.0	6.0	8.0	8.0	5.0	4.0	3.0	4.0	8.0	3.0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals...	354.0	352.0	358.0	354.0	326.0	305.0	282.0	255.5	241.0	239.0	247.0	242.0	270.5	232.0	220.5	243.5	273.0	259.0	275.0	239.0	269.0	289.5	306.5	298.0
	76.0	79.3	82.9	75.4	64.4	54.0	35.0	35.0	34.0	33.0	34.0	38.0	36.0	26.0	30.0	37.2	42.2	31.0	36.0	44.0	48.0	57.0	62.0	60.4

TABLE I. — Continued — *Record of wind velocities and water pumped by windmill on Physical Laboratory Septmeber, 1897.*

Date.	Noon	1	2	3	4	5	6	7	8	9	10	11	M.	1	2	3	4	5	6	7	8	9	10	11
31–1......	14	11	8	4	14	9	7	6	6	8	7	4	7	7	4.5	4.5	15	7	10	15	5	3	6	3
	4	2.1	0	0	4	1	0	6	1	3	0	0	1	0	0	0	5.1	0	1	1	1	2	2	2
1–2......	3	3	4	2	3	6	8	8	12	15	9	5	6	7	8	7	6	7	8	8	10	11	11	10
	0	0	0	0	0	0	1	0	2.5	5.1	1.1	0	0	0	0	1	3	1	3	2	1.4	2.1	2.1	1.4
2–3......	11	10	9	11	11	10	10	10	10	8	7	7	8	8	7	8	6	6	8	11	13	11	13	14
	2	2	0	2	1	2	1.4	1	2	0	0	0	0	1	0	0	0	0	0	1	1	2.1	3.1	4
3–4......	12	11	12	10	11	8	7	9	10	8	10	7	8	10	8	9	9	11	11	11	11	12	15	15
	2.5	2.1	2.5	1.4	2.1	0	0	1	1.4	0	1.4	0	0	1.4	0	1.1	2	2.1	2	2	3	3	5.1	5.1
4–5......	13	14	14	14	13	10	8	8	10	9	10	13	16	20	20	7	7	6	5	6	4	8	15	12
	5	4	4	5	3	1	0	0	1.4	1	2	4	6	6	6	1	0	0	0	0	0	1	5	4
5–6......	11	15	13	11	7	5	5	7	10	10	11	12	11	8	6	7	8	9	8	10	12	13	16	14
	2.1	5.1	3.1	2.1	0	0	0	0	1.4	1.4	2.1	2.5	2.1	0	0	0	0	1.1	0	1.4	2.5	3.1	5.9	4
6–7......	14	15	12	12	7	6	6	7	7	8	8	7	6	8	8	8	9	7	6	4	6	7	8	13
	4	5.1	2.5	2.5	0	0	0	0	0	0	0	0	0	0	0	0	1.1	0	0	0	0	0	0	3.1
7–8......	14	14	15	16	14	10	7	6	8	9	8	10	10	10	10	9	14	12	11	7	2	6	8	14
	4	4	5.1	5.9	4	1.4	0	0	0	1.1	0	1.4	1.4	1.4	1.4	1.1	4	2.5	2.1	0	0	0	0	4
8–9......	13	13	14	15	15	15	9	6	7	8	8	8	10	7	10	8	9	8	10	7	7	9	10	11
	3.1	3.1	4	5.1	5.1	5.1	1.1	0	0	0	0	0	1.4	0	1.4	0	1.1	0	1.4	0	0	1.1	1.4	2.1
9–10......	15	18	16	14	11	6	5	6	9	8	12	14	14	12	12	14	11	8	1	4	3	4	5	5
	5.1	7.5	5.9	4	2.1	0	0	0	1.1	0	2.5	4	4	2.5	2.5	4	2.1	0	0	0	0	0	0	0
10–11......	11	9	5	7	8	6	6	8	8	10	14	12	9	10	11	8	12	13	17	14	13	12	9	5
	2.1	1.1	0	0	0	0	0	0	0	1.4	4	2.5	1.1	1.4	2.1	0	2.5	3.1	7.5	4	3.1	2.5	1.1	0
11–12......	6	5	7	8	6	5	6	8	7	7	7	6	2	5	7	4	1	1	0	1	1	4	2	3
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12–13......	6	10	11	11	10	7	6	6	7	8	6	6	8	8	10	12	5	6	5	7	6	7	7	7
	0	1.4	2.1	2.1	1.4	0	0	0	0	0	0	0	0	0	1.4	2.5	0	0	0	0	0	0	0	0
13–14......	5	4	4	3	5	5	4	7	9	8	10	7	6	5	4	4	4	4	5	6	6	6	6	6
	0	0	0	0	0	0	0	0	1.1	0	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0
14–15......	12	16	15	15	16	10	7	7	8	8	6	7	8	8	10	11	12	10	9	12	11	10	15	14
	2.5	5.9	5.1	5.1	5.9	1.4	0	0	0	0	0	0	0	0	1.4	2.1	2.5	1.4	1.1	2.5	2.1	1.4	5.1	4
15–16......	19	22	26	24	19	18	13	11	12	11	10	7	3	6	6	7	3	14	10	10	6	13	15	18
	7.9	8.9	9.6	9.5	7.9	7.5	3.1	2.1	2.5	2.1	1.4	0	0	0	0	0	0	4	1.4	1.4	0	3.1	5.1	7.5
16–17......	20	23	27	24	23	22	19	19	19	20	21	22	19	17	16	18	17	16	19	17	11	7	6	6
	8.6	9.8	9.6	9.5	9.8	8.9	7.9	7.9	7.9	8.1	8.3	8.9	7.9	7.5	5.9	7.5	7.5	5.9	7.9	7.5	2.1	0	0	0
17–18......	6	3	5	5	5	4	8	9	10	11	11	10	12	15	20	19	16	14	18	17	17	18	16	13
	0	0	0	0	0	0	0	1.1	1.4	2.1	2.1	1.4	2.5	5.1	8.1	7.9	5.9	4	7.5	7.5	7.5	7.5	5.9	3.1
18–19......	19	20	18	19	18	14	11	14	14	13	13	14	16	15	15	14	17	20	25	24	23	21	18	21
	7.9	8.6	7.5	7.9	7.5	4	2.1	4	4	3.1	3.1	4	5.9	5.1	5.1	4	7.5	8.6	9.6	9.5	9.8	8.3	7.5	8.3
19–20......	19	19	21	20	20	19	19	18	19	20	23	17	18	17	15	14	11	6	9	6	5	6	5	4
	7.9	7.9	8.3	8.6	8.6	7.9	7.9	7.5	7.9	8.6	9.8	7.5	7.5	7.5	5.1	4	2.1	0	1.1	0	0	0	0	0
20–21......	3	3	4	5	2	2	3	4	4	6	8	10	10	13	12	14	17	14	14	17	17	21	20	18
	0	0	0	0	0	0	0	0	0	0	0	1.4	1.4	3.1	2.5	4	7.5	4	4	7.5	7.5	8.3	8.6	7.5
21–22......	21	21	21	24	18	12	9	11	8	7	7	3	3	4	4	2	1	5	7	7	10	16	15	12
	8.3	8.3	8.3	9.5	7.5	2.5	1.1	2.1	0	0	0	0	0	0	0	0	0	0	0	0	1.4	5.9	5.1	2.5
22–23......	12	12	12	13	14	10	10	9	7	6	6	5	5	5	2	3	3	4	3	5	4	2	5	6
	2.5	2.5	2.5	3.1	4	1.4	1.4	1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23–24......	5	4	3	4	3	7	9	8	6	6	3	0	1	1	0	0	0	0	0	0	0	2	2	4
	0	0	0	0	0	0	1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24–25......	3	3	3	6	7	6	4	6	5	6	6	7	4	6	8	6	4	6	5	6	6	4	2	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25–26......	12	13	15	13	11	7	6	5	5	2	6	7	5	5	5	9	17	17	9	8	17	21	21	17
	2.5	3.1	5.1	3.1	2.1	0	0	0	0	0	0	0	0	0	0	1.1	7.5	7.5	1.1	0	7.5	8.3	5.1	7.5
26–27......	14	14	21	13	14	11	9	9	9	5	4	7	9	11	11	11	8	7	6	4	6	6	7	5
	4	4	8.3	3.1	4	2.1	1.1	1.1	1.1	0	0	0	1.1	2.1	2.1	2.1	0	0	0	0	0	0	0	0
27–28......	5	6	7	7	7	11	10	10	8	7	5	4	2	4	5	6	6	8	11	12	14	13	12	12
	0	0	0	0	0	2.1	1.4	1.4	0	0	0	0	0	0	0	0	0	0	2.1	2.5	4	3.1	2.5	2.5
28–29......	12	14	11	12	11	9	7	7	8	8	9	9	9	7	8	6	7	6	5	4	6	8	10	9
	2.5	4	2.1	2.5	2.1	1.1	0	0	0	0	1.1	1.1	1.1	0	0	0	0	0	0	0	0	0	1.4	1.1
29–30......	9	9	9	9	8	6	8	7	9	4	7	5	6	4	3	0	0	2	6	6	6	3	10	10
	1.1	1.1	1.1	1.1	0	0	0	0	1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	1.	1.4
Totals...	339.0	354.0	362.0	351.0	331.0	276.0	246.0	256.0	271.0	264.0	272.0	252.0	251.0	263.0	265.5	249.5	255.0	254.0	261.0	266.0	258.0	289.0	310.0	301.0
	89.6	101.6	96.7	93.1	82.1	49.4	30.6	30.3	37.8	37.0	40.3	38.7	44.4	44.1	45.0	43.4	61.4	45.2	52.8	49.8	53.9	62.8	[illegible]	75.1

TABLE I.—Continued.—*Record of wind velocities and water pumped by wind mill on Physical Laboratory during October, 1897.*

Date.	Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	M.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
30— 1......	10	9	9	9	8	8	11	11	4	4	3	6	8	6	5	2	3	0	0	1	5	1	2	2
	1.4	1.1	1.1	1.1	0	0	2.1	2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1— 2......	3	3	4	4	17	11	6	7	6	7	6	5	5	6	6	6	5	5	5	7	9	10	9	8
	0	0	0	0	7.5	2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1	1.4	1.1	0
2— 3......	10	10	11	10	11	12	13	9	8	7	6	5	6	5	9	9	9	9	13	7	6	8	8	6
	1.4	1.4	2.1	1.4	2.1	2.5	3.1	1.1	0	0	0	0	0	0	1.1	1.1	1.1	1.1	3.1	0	0	0	0	0
3— 4......	6	6	5	7	5	5	7	8	8	9	7	11	13	11	13	14	14	14	13	14	17	16	14	12
	0	0	0	0	0	0	0	0	0	1.1	0	2.1	3.1	2.1	3.1	4	4	4	3.1	4	7.5	5.9	4	2.5
4— 5......	19	20	20	20	16	18	9	11	15	18	17	17	20	21	18	16	13	10	10	11	16	16	21	22
	7.9	8.6	8.6	8.6	5.9	7.5	1.1	2.1	5.1	7.5	7.5	7.5	8.6	8.3	7.5	5.9	3.1	1.4	1.4	2.1	5.9	5.9	8.3	8.9
5— 6......	25	26	24	25	25	19	17	17	15	15	15	12	10	10	8	3	3	4	7	6	10	14	20	20
	9.6	9.6	9.5	9.6	9.6	7.9	7.5	7.5	5.1	5.1	5.1	2.5	1.4	1.4	0	0	0	0	0	0	1.4	4	8.6	8.6
6— 7......	26	25	22	25	19	14	18	24	23	18	11	10	13	13	14	15	12	8	8	6	10	8	6	6
	9.6	9.6	8.9	9.6	7.9	4	7.5	9.5	9.8	7.5	2.1	1.4	3.1	3.1	4	5.1	2.5	0	0	0	1.4	0	0	0
7— 8......	6	9	9	9	10	8	9	13	12	13	11	11	13	12	17	20	18	12	15	9	12	14	15	19
	0	1.1	1.1	1.1	1.4	0	1.1	3.1	2.5	3.1	2.1	2.1	3.1	2.5	7.5	8.6	7.5	2.5	5.1	1.1	2.5	4	5.1	7.9
8— 9......	17	20	18	19	20	26	26	21	21	25	23	21	19	17	16	17	17	18	17	12	6	4	5	4
	7.5	8.6	7.5	7.9	8.6	9.6	9.6	8.3	8.3	9.6	9.8	8.3	7.9	7.5	5.9	7.5	7.5	7.5	7.5	2.5	0	0	0	0
9—10......	4	5	5	3	3	4	8	12	9	10	7	6	7	6	7	5	5	4	6	5	8	11	11	14
	0	0	0	0	0	0	0	2.5	1.1	1.4	0	0	0	0	0	0	0	0	0	0	0	2.1	2.1	4
10—11......	13	13	11	6	8	9	9	9	10	12	10	8	10	7	5	4	1	5	3	3	3	2	2	3
	3.1	3.1	2.1	0	0	1.1	1.1	1.1	1.4	2.5	1.4	0	1.4	0	0	0	0	0	0	0	0	0	0	0
11—12......	8	7	8	9	10	8	13	13	16	12	17	16	14	20	20	14	13	8	9	12	16	17	16	16
	0	0	0	1.1	1.4	0	3.1	3.1	5.9	2.5	7.5	5.9	4	8.6	8.6	4.0	3.1	0	1.1	2.5	5.9	7.5	5.9	5.
12—13......	16	16	13	13	13	7	5	5	6	5	4	2	3	5	4	7	9	6	6	7	11	18	20	20
	5.9	5.9	3.1	3.1	3.1	0	0	0	0	0	0	0	0	0	0	0	1.1	0	0	0	2.1	7.5	8.6	8.6
13—14......	18	18	18	16	16	14	15	12	12	16	22	22	21	19	21	23	22	20	20	22	30	32	35	32
	7.5	7.5	7.5	5.9	5.9	4	5.1	2.5	2.5	5.9	8.9	8.9	8.3	7.9	8.3	9.8	8.9	8.6	8.6	8.9	9.1	10	10	10
14—15......	31	31	32	28	25	22	22	21	19	18	18	13	14	14	11	13	12	13	13	13	16	19	22	22
	10	10	10	9.8	9.6	8.9	8.9	8.3	7.9	7.5	7.5	3.1	4	4	2.1	3.1	2.5	3.1	3.1	3.1	5.9	7.9	8.9	8.9
15—16......	26	23	23	22	17	12	14	21	21	20	17	14	15	18	14	15	13	10	20	23	23	12	22	14
	9.6	9.8	9.8	8.9	7.5	2.5	4	8.3	8.3	8.6	7.5	4	5.1	7.5	4	5.1	3.1	1.4	8.6	9.8	9.8	2.5	8.9	4
16—17......	18	21	17	15	17	15	12	17	16	16	16	17	17	17	15	16	12	12	9	5	7	7	7	7
	7.5	8.3	7.5	5.1	7.5	5.1	2.5	7.5	5.9	5.9	5.9	7.5	7.5	7.5	5.1	5.9	2.5	2.5	1.1	0	0	0	0	0
17—18......	7	7	8	11	10	10	12	11	10	8	7	4	6	6	6	7	8	10	10	10	11	11	7	9
	0	0	0	2.1	1.4	1.4	2.5	2.1	1.4	0	0	0	0	0	0	0	0	1.4	1.4	1.4	2.1	2.1	0	1.1
18—19......	9	8	8	11	5	6	9	10	9	9	5	6	7	6	4	5	6	9	9	8	11	12	11	12
	1.1	0	0	2.1	0	0	1.1	1.4	1.1	1.1	0	0	0	0	0	0	0	1.1	1.1	0	2.1	2.5	2.1	2.5
19—20......	13	12	12	12	12	10	11	12	9	8	9	6	7	5	6	7	7	8	8	7	11	11	10	10
	3.1	2.5	2.5	2.5	2.5	1.4	2.1	2.5	1.1	0	1.1	0	0	0	0	0	0	0	0	0	2.1	2.1	1.4	1.4
20—21......	11	13	14	12	11	12	14	15	12	12	12	16	13	10	14	13	12	13	14	13	13	14	15	13
	2	4	5	4	3	2	2	4	2	2	4	5	2	1	4	2	1	2	4	3	3	2	3	3
21—22......	11	13	12	14	13	8	9	7	9	9	11	11	10	10	11	7	7	5	6	8	6	5	2	2
	4	1	3	3	1	0	0	0	0	1	3	1	1	1	1	0	0	0	0	0	0	0	0	0
22—23......	3	1	1	3	3	5	7	6	6	7	7	7	9	8	8	8	9	9	9	11	8	10	12	13
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1	1.1	1.1	2.1	0	1.4	2.5	3.1
23—24......	13	14	12	11	9	7	7	9	9	9	7	7	8	8	6	7	6	6	8	9	6	6	9	11
	0	4	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
24—25......	13	13	12	11	8	7	8	8	7	7	8	7	6	7	8	9	7	8	6	5	6	7	10	13
	3	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4
25—26......	15	12	13	9	10	9	9	6	7	8	4	5	6	5	4	6	5	2	6	2	4	2	4	6
	4	4	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26—27......	4	6	7	6	7	7	7	5	6	4	3	3	0	0	2	3	3	5	1	1	3	1	4	2
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27—28......	4	5	5	0	0	2	6	7	8	8	13	14	15	14	11	11	12	11	15	15	13	11	13	14
	0	0	0	0	0	0	0	0	0	2	3	5	5	4	2	1	3	3	4	4	3	2	3	3
28—29......	16	18	23	20	18	16	14	14	12	14	12	12	15	13	8	5	4	2	4	4	1	8	12	12
	5	8	11	9	9	5	4	5	0	3	1	4	5	2	0	0	0	0	0	0	0	1	2	3
29—30......	13	12	12	14	11	6	7	11	13	21	18	15	10	11	14	14	13	15	16	14	12	10	7	5
	4	3	3	4	2	0	0	1	5	6	6	4	4	4	5	3	3	5	3	3	2	1	0	0
30—31......	4	5	1	2	2	1	7	3	4	3	3	5	5	6	4	6	4	4	2	3	2	1	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals...	392.0	401.0	389.0	376.0	359.0	318.0	341.0	355.0	342.0	350.0	329.0	314.0	325.0	316.0	309.0	307.0	284.0	265.0	288.0	273.0	312.0	318.0	351.0	349.0
	107.2	114.1	111.3	103.9	96.9	65.0	68.4	83.0	74.4	83.3	82.3	72.3	74.5	72.4	69.2	66.1	55.0	45.7	57.3	47.5	66.9	72.8	89.5	90.4

TABLE I.—Continued.—*Records of wind velocities and water pumped by windmill on Physical Laboratory during November, 1897.*

Date.	Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	M.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
31—1......	4	10	10	11	13	12	10	12	12	12	13	16	16	12	21	24	24	25	21	31	34	29	32	32
	0	1	0	2	4	3	1	4	3	3	4	6	5	5	6	7	7	6	7	11	11	10	10	11
1—2......	31	33	30	28	28	21	14	16	15	13	16	15	18	14	16	16	11	10	14	16	15	18	15	14
	11	11	11	9	9	10	6	6	4	3	5	6	6	6	5	5	4	4	7	6	4	9	7	6
2—3......	14	12	11	10	9	5	5	5	5	4	5	5	6	2	4	5	8	8	8	8	5	7	11	15
	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5
3—4......	18	15	18	17	15	10	10	15	18	19	16	13	11	12	11	10	13	17	16	21	24	21	14	11
	9	7	9	7	4	0	0	8	10	9	6	4	1	2	3	1	4	5	7	11	11	10	6	4
4—5......	13	14	13	8	8	2	3	6	7	8	9	13	10	9	11	10	7	9	13	14	13	18	26	28
	4	4	4	1	0	0	0	0	0	0	0	4	1	1	2	1	0	1	3	5	3	6	12	11
5—6......	28	27	27	26	22	26	22	23	29	23	15	11	13	16	7	10	11	6	7	8	9	6	4	1
	14	10	8	9	9	10	12	10	12	6	2	1	3	3	0	0	0	0	0	0	0	0	0	0
6—7......	2	6	10	9	7	5	6	5	3	3	6	4	3	1	7	6	3	6	5	5	5	5	6	10
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
7—8......	13	9	6	5	4	4	3	4	2	3	3	3	7	10	12	14	14	14	11	12	14	21	17	14
	3	1	0	0	0	0	0	0	0	0	0	0	1	5	5	5	6	6	4	4	9	11	9	6
8—9......	15	16	18	22	21	21	24	21	22	24	26	30	28	27	16	14	17	15	14	19	18	19	17	12
	8	8	11	12	10	11	11	11	11	13	11	10	11	12	12	11	8	6	6	9	10	9	7	2
9—10......	12	7	6	6	3	2	6	6	10	11	10	11	13	11	11	14	14	14	15	13	15	16	16	18
	1	0	0	0	0	0	0	0	2	1	2	3	3	2	3	5	5	3	5	4	3	5.9	5.9	7.5
10—11......	19	25	29	26	28	19	17	18	15	14	16	19	19	20	31	34	36	38	34	29	28	35	32	31
	7.9	11	12	12	11	9	8	8	5	4	6	6	7	6	7	6	6	6	10	9	9	13	12	12
11—12......	29	31	30	30	22	25	22	22	21	22	19	14	17	18	14	14	9	8	13	13	12	12	10	11
	11	13	9	11	11	10	10	10	6	6	6	4	5	5	4	4	0	1	4	3	2	2	1	0
12—13......	9	6	9	6	6	4	4	5	7	9	7	6	9	9	12	13	11	8	10	7	6	10	9	8
	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	3	1	1	0	0	0	1	0	2
13—14......	7	8	8	8	9	10	11	13	12	12	10	10	12	14	14	16	16	16	18	14	12	9	5	6
	1	0	0	1	1	2	3	3	3	3	2	2	3	4	5	5	5	5	5	4	3	0	0	0
14—15......	7	6	5	4	5	3	1	1	1	3	4	8	10	10	12	15	11	13	19	17	22	21	17	18
	0	0	0	0	0	0	0	0	0	0	1	0	1	2	4	4	2	5	8	7	10	7	9	10
15—16......	15	17	18	23	24	21	24	26	21	24	27	25	26	26	26	29	27	25	23	19	21	19	17	17
	8	5	9	10	11	10	11	9	7	8	12	11	10	10	10	9	5	7	6	9	6	7	8	6
16—17......	16	14	15	15	11	7	7	7	8	6	5	7	6	3	5	5	5	5	5	5	5	6	7	9
	6	4	7	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1
17—18......	10	10	8	4	5	5	6	6	6	6	7	6	7	8	7	3	5	7	7	7	9	9	9	10
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0
18—19......	13	14	16	17	12	10	9	12	15	15	12	7	4	4	7	10	8	7	9	8	5	10	8	9
	4	5	7	7	3	1	0	4	6	5	2	1	0	0	0	0	0	0	0	0	0	1	1	0
19—20......	10	13	11	12	15	14	12	11	8	15	13	6	9	7	6	9	17	22	16	12	14	16	17	17
	1	4	3	4	4	5	1	0	1	9	2	1	0	0	0	1	8	12	4	3	4	8	8	8
20—21......	21	19	14	13	10	10	16	21	17	14	15	14	11	22	18	22	23	20	19	21	20	20	20	15
	11	7	4	2	2	2	5	6	5	4	4	3	4	6	5	6	6	6	8	10	10	10	11	6
21—22......	17	17	16	17	17	17	21	20	16	17	15	16	16	17	18	19	18	15	13	10	9	12	11	11
	10	6	7	8	9	8	10	9	8	7	7	6	7	8	10	9	9	6	3	1	2	2	2	2
22—23......	13	11	13	14	13	12	16	18	17	21	21	24	22	21	24	21	20	19	20	18	15	14	13	11
	3	2	4	3	4	3	5	5	5	6	7	6	7	6	6	6	6	4	7	7	5	3	3	2
23—24......	11	11	11	10	7	5	9	10	8	10	10	9	7	9	10	10	13	13	17	19	21	22	24	24
	3	3	2	2	0	0	1	0	0	1	1	1	0	0	2	1	3	2	5	9	10	11	11	12
24—25......	23	24	22	21	17	19	20	17	15	14	8	4	6	6	6	7	7	6	7	5	5	3	5	4
	12	11	10	10	7	10	9	8	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25—26......	5	8	8	14	14	10	8	7	7	13	14	17	15	17	19	25	32	29	27	29	34	32	30	29
	0	0	2	5	3	2	0	0	0	4	5	5	5	6	6	7	7	6	8	12	12	11	11	10
26—27......	25	25	25	23	22	20	23	20	20	22	19	18	18	17	15	13	9	8	7	7	6	6	4	5
	10	11	11	11	10	10	10	9	10	10	9	7	5	5	4	3	1	0	0	0	0	0	0	0
27—28......	6	5	6	5	3	3	5	3	4	5	4	7	6	3	4	3	4	8	11	7	7	6	9	12
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3
28—29......	13	12	12	9	12	14	15	15	18	16	20	20	21	23	20	14	10	9	8	10	10	9	11	14
	4	3	2	0	3	4	5	4	6	4	6	7	6	6	6	3	3	3	0	0	2	1	3	5
29—30......	17	18	14	12	6	9	10	8	9	7	8	7	5	4	4	7	5	8	9	12	11	17	18	22
	7	6	5	2	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	2	2	5	8	12
Totals.	436.0 151.9	443.0 135.0	439.0 139.0	425.0 136.0	388.0 116.0	345.0 112.0	359.0 110.0	373.0 114.0	368.0 110.0	385.0 110.0	373.0 100.0	365.0 94.0	371.0 92.0	372.0 102.0	388.0 107.0	412.0 102.0	408.0 98.0	408.0 95.0	416.0 108.0	416.0 126.0	424.0 129.0	448.0 142.9	434.0 148.9	438.0 145.6

TABLE I.—Continued.—*Record of wind velocities and water pumped by windmill on Physical Laboratory during December, 1897.*

Date.	N n	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	M.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
30— 1......	23	19	17	15	16	11	9	4	1	2	3	10	16	21	22	18	20	21	17	15	16	14	15	11
	11	8	7	6	5	2	0	0	0	0	0	3	5	6	6	5	6	8	7	5	4	4	4	1
1— 2......	13	14	13	11	12	14	16	17	16	15	9	10	12	11	8	9	7	8	6	4	7	6	4	7
	4	3	1	2.1	1	4	5	4	5	4	1.1	1	1	2	0	0	0	0	0	0	0	0	0	0
2— 3......	11	11	9	11	12	11	12	12	10	12	13	13	15	18	19	21	18	16	15	13	14	15	15	13
	1	1	1.1	2.1	2.5	4	1	2	2	1	4	3	4	6	6	6	6	6	5	3	4	5	5	4
3— 4......	18	16	16	22	18	18	18	23	19	20	18	17	20	18	19	20	13	8	11	12	14	17	19	12
	10	7	8	10	8	9	11	10	10	10	8	7	9	8	9	10	1	1	2	4	5	6	7	2
4— 5......	11	8	7	4	5	7	9	8	11	11	12	11	11	14	10	6	6	5	7	10	11	9	12	9
	0	0	2	0	0	1	1	0	3	4	3	2	3	3	1	0	0	0	1	1	0	1	3	1
5— 6......	11	11	10	7	4	5	6	4	4	7	7	9	10	7	11	12	16	18	22	19	21	21	22	22
	2	2	1	0	0	0	0	0	0	0	0	1	1	0	1	3	5	6	10	6	10	11	10	11
6— 7......	20	21	21	18	14	13	10	12	22	20	20	20	18	16	15	12	11	6	7	6	5	6	3	5
	11	10	10	8	4	3	1.4	4	7	6	7	6	7	5	6	2	2	0	0	1	0	0	0	0
7— 8......	5	6	5	7	10	11	7	1	6	11	14	15	19	13	12	5	9	7	5	7	5	7	9	9
	0	0	0	0	2	3	1	0	0	1	5	9	10	6	3	0	0	0	0	0	0	0	0	0
8— 9......	7	10	8	7	7	8	11	9	21	14	13	13	14	15	15	17	15	14	8	7	7	7	12	10
	0	0	1	0	0	0	2	2	7	5	4	4	4	4	6	5	6	4	2	0	0	0	2	1
9—10......	12	7	6	4	2	6	6	7	6	7	9	4	6	5	4	6	9	10	10	11	13	12	15	17
	3	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1.4	1.4	3	3	2.5	5.1	7.5
10—11......	17	16	16	12	10	14	17	18	20	20	23	20	18	17	16	14	14	12	13	10	9	7	8	6
	7	9	7	2.5	2	4	6	6	7	6	7	7	6	5	5	4	4	3	3	0	0	1	0	0
11—12......	6	5	4	4	5	4	4	4	4	6	4	3	6	5	4	5	3	3	2	2	2	2	2	2
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12—13......	2	2	2	3	3	4	7	9	9	9	7	6	7	8	10	11	14	13	14	17	16	19	20	20
	0	0	0	0	0	0	1	1	0	0	0	0	1	0	2	2.1	4	4	5	7	9	9	9	9
13—14......	23	23	20	23	19	20	24	28	29	28	26	23	23	27	24	26	24	22	23	21	20	20	18	15
	9.8	9.8	8.6	9.8	11	11	12	10	6	10	11	12	11	12	11	12	11	12	10	11	10	10	9	9
14—15......	17	17	15	13	13	13	10	5	5	5	5	3	4	3	2	1	2	1	6	5	5	9	13	15
	10	9	5	1	1	3.1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	5
15—16......	19	20	19	18	21	18	17	16	13	14	15	18	18	26	32	26	18	25	24	21	17	18	14	16
	10	10	10	8	9	8	7	7	2	3	7	9	9	10	9	11	11	9	9	8	9	9	5	7
16—17......	16	16	14	15	12	15	8	8	10	8	7	8	8	12	13	15	15	11	10	10	9	9	8	11
	9	8	5	6	1	1	0	0	1	0	0	0	0	2	3	4	3	3	0	0	0	0	0	1
17—18......	14	10	14	13	12	9	9	11	11	9	7	7	8	8	10	12	8	10	8	7	10	8	5	7
	3	1	4	3	2.5	1.1	2	2.1	2.1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
18—19......	6	7	6	5	5	2	4	8	7	4	5	5	4	3	3	4	4	3	2	2	1	0	2	3
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19—20......	1	1	1	3	4	5	3	1	3	3	1	0	4	5	2	4	5	6	8	10	11	11	12	10
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	2	1
20—21......	10	12	8	7	6	7	8	7	8	6	6	7	8	4	8	9	5	3	2	5	2	0	0	0
	1.4	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
21—22......	5	8	9	8	6	7	10	11	9	8	8	14	10	7	7	10	9	6	12	12	11	8	9	10
	0	0	0	0	0	0	1	2.1	1	0	1	5	2	0	0	2	0	1	2	3	2	1	1.1	1
22—23......	10	11	8	8	11	9	13	9	14	11	10	11	13	16	16	17	14	10	13	12	11	14	13	19
	2	2	0	1	2.1	1.1	4	1.1	3	1	1	1	3	5	4	5	4	0	3	2	0	0	2	8
23—24......	18	17	17	15	12	10	9	11	8	8	6	1	3	4	1	3	2	4	8	7	10	12	15	15
	9	7	8	3	2.5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2.5	4	6
24—25......	15	14	14	12	13	18	20	26	23	25	27	26	16	20	17	22	20	17	17	14	13	13	13	14
	3	4	3	1	4	8	10	12	11	11	11	10	7	8	7.5	8.9	8.6	7.5	7.5	3	4	4	3	4
25—26......	10	13	11	7	14	16	13	11	9	11	13	14	14	13	18	17	18	17	22	16	11	15	17	16
	1	4	2	0	4	4	4	1	1.1	3	5	5	4	3	5	5	5	5	8	6	2.1	5	9	8
26—27......	15	17	14	15	11	9	9	11	9	9	5	4	4	3	0	0	1	1	1	0	0	1	1	3
	6	8	5	6	4	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27—28......	4	1	2	4	2	1	0	0	0	0	0	0	1	0	2	4	3	4	4	6	5	6	7	10
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28—29......	10	10	11	8	10	12	14	16	22	20	24	23	27	32	26	18	19	22	27	26	25	24	27	32
	1	0	2	0	0	3	4	5	6	6	7	6	6	7	6	4	5	6	11	11	10	9	11	10
29—30......	30	29	26	20	21	14	12	15	17	20	15	15	11	13	14	12	15	12	15	13	17	14	15	16
	13	10	8	8	8.3	4	4	5	6	6	5	4	3	5	5	4	5	3	5	2	7	6	8	6
30—31......	16	17	16	12	16	18	19	17	15	16	16	18	16	14	17	16	15	15	19	18	22	25	25	25
	6	5	4	2.5	5.9	9	10	6	5	6	7	9	5	5	8	9	5	5	7	7	11	11	12	8
Totals...	395.0 133.2	389.0 119.8	359.0 102.7	331.0 80.0	326.0 79.8	329.0 84.3	334.0 89.4	339.0 84.3	351.0 85.2	359.0 83.0	348.0 95.1	348.0 105.0	364.0 101.0	378.0 102.0	377 0 104.5	372.0 103.0	352.0 91.6	330.0 85.9	358.0 99.9	338.0 83.0	340.0 94.1	349.0 99.0	370.0 115.2	380.0 110.5

TABLE I.—Continued—*Record of wind velocities and water pumped by windmill on Physical Laboratory during January, 1898.*

Date.	Noon	1	2	3	4	5	6	7	8	9	10	11	M.	1	2	3	4	5	6	7	8	9	10	11
31— 1......	23	26	23	24	21	23	22	19	17	16	15	16	15	16	21	21	22	20	15	16	16	17	16	15
	12	11	11	10	10	11	10	8	7	4	4	6	5	4	9	11	10	10	10	8	7	7	7	4
1— 2......	13	12	13	10	8	11	9	12	10	7	6	6	7	10	10	16	12	14	18	22	33	30	30	26
	3	1	3	0	0	1	0	2	0	0	0	0	0	1	1	4	1	2	8	10	11	11	11	9
2— 3......	25	25	20	11	11	11	12	13	12	15	13	10	8	6	6	5	5	1	1	3	6	4	5	8
	11	12	11	3	1	2	2.5	1	2.5	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0
3— 4......	7	7	7	8	7	6	7	8	6	3	5	2	1	2	2	2	4	7	16	15	15	14	12	16
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.9	5.1	5.1	4	2.5	5.9
4— 5......	12	12	14	16	13	11	15	15	13	12	12	12	13	9	10	7	7	9	6	8	7	8	8	10
	2.5	2.5	4	5.9	3.1	2.1	5.1	5.1	3.1	2.5	2.5	2.5	3.1	1.1	1.4	0	0	1.1	0	0	0	0	0	1
5— 6......	12	12	9	9	9	13	16	23	16	21	23	20	19	21	15	11	13	13	11	16	14	25	23	18
	3	2	1	1.1	1.1	4	5	6	5	6	7	6	6	5	3	2	2	2	5	8	6	10	11	8
6— 7......	23	21	19	13	10	7	8	7	6	5	4	8	8	7	8	7	8	9	9	11	18	17	19	21
	10	9	7	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2	5	9	10
7— 8......	24	24	19	19	14	8	11	18	16	15	15	18	22	25	24	20	20	15	15	14	17	16	13	11
	10	11	9	9	5	0	1	5	6	5	5	6	7	6	6	6	5	5	3	8	7.5	7	3	1
8— 9......	10	14	12	9	6	6	7	7	7	8	5	4	9	7	9	6	4	7	9	5	5	4	2	2
	2	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9—10......	3	4	3	6	6	7	3	4	5	4	4	5	5	8	8	6	7	7	8	6	8	10	10	8
	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0
10—11......	10	10	9	12	10	8	9	12	6	6	2	1	3	3	1	3	2	4	8	7	5	9	4	3
	0	1	1.1	1	1.4	1	1.1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
11—12......	1	1	2	2	3	1	2	2	1	5	8	4	6	8	9	17	18	18	18	20	20	24	19	21
	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	5	6	5	6	8.6	8.6	13	11	8
12—13......	23	27	23	20	20	20	23	25	22	20	18	18	14	12	11	9	5	5	5	0	1	2	6	6
	12	11	11	10	10	8	12	11	11	11	9	10	3	2	2.1	0	0	0	0	0	0	0	0	0
13—14......	10	9	6	6	5	6	10	11	8	10	11	5	8	7	9	5	5	4	4	6	6	3	6	10
	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
14—15......	7	4	6	2	5	5	3	5	3	4	0	3	3	4	7	4	1	7	12	12	13	18	19	16
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	4	6	9
15—16......	19	17	13	13	12	11	12	9	9	10	9	5	5	8	6	3	4	3	0	0	0	4	6	4
	11	6	4	2	2.5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16—17......	1	4	5	5	6	5	6	6	6	5	6	7	5	0	4	6	3	5	7	3	4	5	6	5
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17—18......	5	4	4	3	4	3	1	0	0	0	1	0	0	0	0	2	0	1	2	0	0	0	2	2
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18—19......	3	2	4	5	5	3	6	6	8	9	9	10	11	7	10	10	12	12	14	11	9	7	3	2
	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2.5	2.5	5	2	0	6	0	0
19—20......	5	6	4	5	4	3	6	8	13	14	14	20	22	32	32	34	39	40	38	31	33	28	24	20
	0	0	0	0	0	0	0	0	1	1	1	8	8	15	15	15	15	15	11	10	10	10	10	8.6
20—21......	21	19	16	14	9	9	7	5	4	7	11	5	7	11	13	14	11	10	9	14	10	8	9	9
	4	9	7	4	1.1	1.1	0	0	0	0	1	0	0	2.1	1	4.0	2.1	0	0	2	1	0	0	0
21—22......	9	10	12	7	5	4	6	5	6	5	4	4	5	9	10	8	5	5	5	12	15	9	10	16
	1	1.4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	1.1	1	3
22—23......	17	19	21	26	29	35	46	40	43	45	45	45	40	37	34	33	29	26	24	20	18	17	17	18
	5	9	11	11	10	10	12	11	15	15	15	15	15	15	10	10	8	8	7	9	8	7	5	7
23—24......	16	16	14	7	6	7	5	3	1	1	0	1	0	0	1	0	0	1	1	0	1	1	1	1
	5	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24—25......	3	5	6	6	5	5	4	5	6	5	5	4	5	11	8	5	15	21	23	25	28	38	38	16
	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3	5	9	11	12	7	10	4
25—26......	28	40	36	37	34	26	24	19	18	16	16	13	17	15	16	13	13	10	11	10	3	4	5	8
	10	15	15	15	15	15	15	15	15	5.9	5.9	3.1	7.5	5.1	5.9	3.1	3.1	1.4	2.1	0	0	0	0	0
26—27......	8	10	12	13	16	16	21	20	14	15	13	10	14	14	11	12	10	9	7	7	6	4	7	6
	1	0	0	3	5.9	7	10	9	5	5	0	1.4	1	2	0	0	0	0	0	0	0	0	0	0
27—28......	4	4	2	2	5	6	7	10	7	5	4	5	7	9	10	11	10	14	12	13	14	14	21	24
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	1	2	5	4	11	9
28—29......	26	26	27	24	21	23	26	26	23	21	19	16	19	18	17	16	11	9	10	9	7	7	4	4
	10	10	9.6	9.5	8	10	8	7	9.8	8.3	7.9	5.9	7.9	7.5	7.5	5.9	2.1	0	0	0	0	0	0	0
29—30......	3	3	1	3	4	5	6	5	6	3	4	5	6	7	4	3	2	2	2	1	4	5	10	14
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4
30—31......	17	16	14	19	18	13	12	14	14	22	24	24	26	27	28	25	28	31	28	28	29	32	34	34
	5	4	4	6	4	3.1	2.5	4	4	8.9	9.5	9.5	9.6	9.6	9.8	9.6	9.8	10	9.8	8	8	3	11	9
Totals...	388.0	409.0	376.0	358.0	331.0	317.0	352.0	362.0	328.0	334.0	325.0	306.0	330.0	350.0	354.0	334.0	325.0	339.0	318.0	335.0	365.0	384.0	389.0	374.0
	117.5	128.9	113.7	91.5	79.1	77.3	85.2	88.1	84.4	76.8	71.8	73.4	74.1	78.4	76.7	76.6	70.6	70.0	83.8	95.7	98.2	95.1	111.5	100.5

TABLE I.—Continued.—*Record of wind velocities and water pumped by windmill on Physical Laboratory during February, 1898.*

Date.	Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	M.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
30— 1......	28	27	29	29	27	21	20	20	21	23	23	18	18	20	17	16	14	12	12	13	11	8	9	8
	7	9	9.8	9.8	9	8.3	10	10	11	11	11	9	10	10	8	8	4	2.5	2	3	0	0	0	0
1— 2......	4	6	7	9	11	11	13	11	13	16	12	12	14	15	20	33	30	30	28	32	33	31	30	26
	0	0	0	1	2.1	1	2	1	3	4	3	1	4	5	6	6	6	6	9	9	10	9	9	7
2— 3......	24	23	20	22	16	15	15	11	7	9	9	10	16	14	15	19	19	21	19	24	22	17	17	15
	11	11	9	10	7	4	4	2	0	0	0	1	3	3	4	5	5	5	7	11	10	8	7	4
3— 4......	17	18	16	14	12	6	8	6	7	9	7	6	5	5	8	9	11	11	14	14	16	16	20	18
	5	9	6	3	1	0	0	0	0	0	0	0	0	0	1	0	2.1	2.1	3	3	5	5	6	8
4— 5......	19	18	20	17	13	10	10	11	8	4	4	10	21	27	28	33	28	22	24	19	16	20	18	11
	8	10	10	7	3	1	1	3	0	0	0	3	6	7	7	7	8	7	9	9	4	8.6	7.5	2.1
5— 6......	13	7	6	5	0	0	8	8	8	11	9	8	9	11	14	18	16	12	14	16	15	21	28	24
	3.1	0	0	0	0	0	0	0	0	2	0	0	0	2	5	5	4	5	3	6	7	8	10	6
6— 7......	28	30	25	27	25	18	29	29	20	22	21	19	22	12	5	6	5	5	3	4	4	5	6	7
	12	7	12	10	10	10	10	17	10	10	9	10	10	5	0	0	0	0	0	0	0	0	0	0
7— 8......	10	9	7	8	8	8	8	9	6	6	5	7	7	8	7	4	1	5	6	6	6	5	3	3
	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8— 9......	5	7	4	5	5	5	5	7	8	9	6	5	3	4	6	5	4	2	3	3	2	1	2	1
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9—10......	2	1	2	4	6	4	4	7	5	4	9	8	7	8	7	6	4	5	6	8	8	7	8	7
	0	0	0	0	0	0	0	1	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
10—11......	6	6	6	5	9	12	11	10	10	11	9	12	12	12	14	9	10	10	10	10	12	15	14	15
	0	0	0	0	1	4	1	1.4	1.4	2.1	1	2	2	3	3	2	1	1	0	1	4	4	5	4
11—12......	13	16	15	15	14	13	13	9	10	10	11	14	15	16	14	15	11	10	13	11	10	10	4	6
	4	5	5	4	5	4	3	1	1	2	2	4	5	5	4	4	2	2	2	1	1	0	0	0
12—13......	8	7	8	11	11	9	10	10	10	13	11	11	12	12	10	11	17	19	20	20	17	22	16	17
	0	0	0	3	3	1	1	1	2	4	3	3	3	4	2	2	5	6	5	9	9	9	6	8
13—14......	16	19	16	23	21	22	26	24	26	22	19	19	20	18	15	11	7	6	8	6	6	8	8	9
	6	9	9	8	10	9	9	10	8	11	9	10	10	10	2	1	0	0	0	0	0	1	0	1.1
14—15......	9	12	11	10	8	8	13	17	18	18	24	27	31	34	33	33	32	25	20	19	16	21	19	15
	0	1	2	2	1	0	2	5	6	6	6	7	5	6	6	7	6	7	10	10	8	9	11	9
15—16......	16	18	15	13	13	8	5	4	6	6	9	10	10	9	6	7	6	7	6	7	11	10	9	7
	5	7	6	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
16—17......	10	12	14	17	17	19	21	21	17	20	21	20	20	22	19	17	14	14	18	19	18	17	15	13
	1	2	4	5	7	9	10	10	8	9	10	10	9	10	9	7	5	6	7	8	9	8	8	5
17—18......	14	17	15	13	13	18	16	17	20	22	22	22	21	21	18	19	15	17	19	17	17	17	14	11
	8	9	8	3	3	8	7	9	8	6	7	6	6	6	6	6	4	6	6	8	8	9	5	2.1
18—19......	10	11	11	12	13	11	11	14	14	16	15	14	15	16	20	20	25	27	26	29	28	23	24	24
	1	2	2	3	5	2.1	4	4	5	5	4	4	5	3	6	6	5	7	10	11	11	10	10	8
19—20......	22	20	23	24	23	24	21	18	21	22	26	26	28	31	29	35	38	40	42	40	40	40	41	39
	11	10	11	12	11	11	10	9	10	11	13	11	9.8	10	9.9	10	10	10	10	10	10	10	10	10
20—21......	38	38	38	35	34	29	30	29	27	28	32	27	26	26	26	25	26	27	27	27	25	27	29	26
	10	10	10	10	10	9.9	9.9	9.9	9.6	9.8	10	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.9	9.6
21—22......	26	24	23	22	17	13	12.0	12	12	14	23	18	17	18	19	18	16	12	6	7	8	9	9	7
	9.6	9.5	9.8	8.9	7.5	3.1	2.5	2.5	2.5	4	9.8	7.5	7.5	7.5	7.9	7.5	5.9	2.5	0	0	0	1.1	1.1	0
22—23......	6	5	2	1	1	0	2	8	4	2	1	1	2	3	2	2	1	3	5	6	7	10	10	17
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	1.4	7.5
23—24......	16	19	23	21	23	22	18	19	19	16	12	15	15	15	14	16	17	15	13	10	15	19	20	20
	5.9	7.9	9.8	8.3	9.8	8.9	7.5	7.9	7.9	5.9	2.5	5.1	5.1	5.1	4	5.9	7.5	5.1	3.1	1.4	5.1	7.9	8.6	8.6
24—25......	24	20	24	19	19	19	19	19	17	16	14	15	15	16	18	17	15	12	11	11	7	8	5	8
	9.5	8.6	9.5	7.9	7.9	7.9	7.9	7.9	7.5	5.9	4	5.1	5.1	5.9	7.5	7.5	5.1	2.5	2.1	2.1	0	0	0	0
25—26......	11	13	11	14	9	7	6	7	8	9	10	8	8	8	6	7	7	8	6	2	1	1	2	4
	2.1	3.1	2.1	4	1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26—27......	7	5	6	8	8	8	7	5	4	3	2	1	3	4	4	5	5	5	3	3	2	2	1	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27—28......	4	4	4	5	5	5	2	3	1	2	2	2	0	0	2	3	3	0	1	1	1	0	1	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals...	406.0 119.2	412.0 131.1	401.0 135.0	408.0 122.9	381.0 116.4	345.0 103.2	365.0 99.8	365.0 102.6	347.0 100.9	363.0 108.7	368.0 107.3	365.0 109.3	392.0 115.1	405.0 117.1	396.0 107.9	419.0 106.5	397.0 95.2	384.0 92.3	383.0 97.8	384.0 112.1	373.0 112.7	390.0 118.6	382.0 115.5	348.0 100.0

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